March 1960

75¢

EMICONDUCTOR PRODUCTS

1960 IRE INTERNATIONAL CONVENTION — TECHNICAL PROGRAM

	Waldorf-Astoria Hotel						New York Coliseum		
	Starlight Roof	Astor Gallery	Jade Room	Sert Room	Empire Room	Grand Ballroom	Faraday Hall	Marconi Hall	Morse Hall
	Session 1 Control Theory	Session 2 The Brookhaven Alternating-Gradient Synchrotron; Transistorized Nuclear Instrumentation	Session 3 The Engineer Writes and Speaks	Session 4 Radio Frequency Interference	Session 5 Engineering Management-I		Session 6 Advances in Aerospace Subsystems	Session 7 Production Techniques	Session 8 Electronic Devices
ch 22 2:30 p.m.	Session 9 Control Applications	Session 10 Direct Conversion	Session 11 Broadcasting-I	Session 12 Audio		Session 13 * Engineering Management-II	Session 14 Varied Views of Medical Electronics	Session 15 Modern Approaches for Improved Air Traffic Management	Session 16 Broadening Device Horizons
arch 22 p.m.	Session 17 Radar and Coding Theory	Session 18 Industrial Electronic Instrumentation	Session 19 Broadcasting-II	Session 20 Audio and Broadcast and Television Receivers			Session 21 The Human as Originator of Signals and Schemes	Session 22 Design of Equipment Reliability	Session 23 Microwave Tubes
, March 22 0:30 p.m.						Session 24 *Panel:* Electronics – Out of This World			
sday, March 23 a.m. - 12:30 p.m.	Session 25 Detection Theory and Applications to Physics	Session 26 Broadcast and Television Receivers	Session 27 Electronic Component Parts	Session 28 Space Telemetry		Session 29 * Seminar on 1959 ITU Geneva Conferences	Session 30 Communication Systems Design	Session 31 Aspects of Component Reliability	Session 32 Microwave Filters
nesday, March 23 0 - 5:00 p.m.	Session 33 Electronic Computers and Circuit Theory: How Each Technology Can Help the Other	Session 34 Ultrasonics Engineering-I	Session 35 Component Parts	Session 36 Stereophonic Sound Reproduction			Session 37 Communication System Techniques	Session 38 Antenna Pattern Synthesis	Session 39 Microwave Interaction with Matter
Thursday, March 24 10:00 a.m. - 12:30 p.m.	Session 40 Adaptive Networks	Session 41 Circuit Theory: Current Contributions	Session 42 Ultrasonics Engineering-II	Session 43 Equipment and Systems	Session 44 Satellite Communications		Session 45 Human Factors in Electronics	Session 46 Scanning Antenna Arrays	Session 47 Magnetic Recording
Thursday, March 24 2:30 - 5:00 p.m.	Session 48 Electronic Computers	Session 49 Symposium on a Decade of Progress in Network Theory	Session 50 Space Electronics	Session 51 Check-Out Instrumentation and Circuitry			Session 52 Vehicular Communications	Session 53 Antenna and Propagation Problems	Session 54 Waveform Analysis and Random Vibration

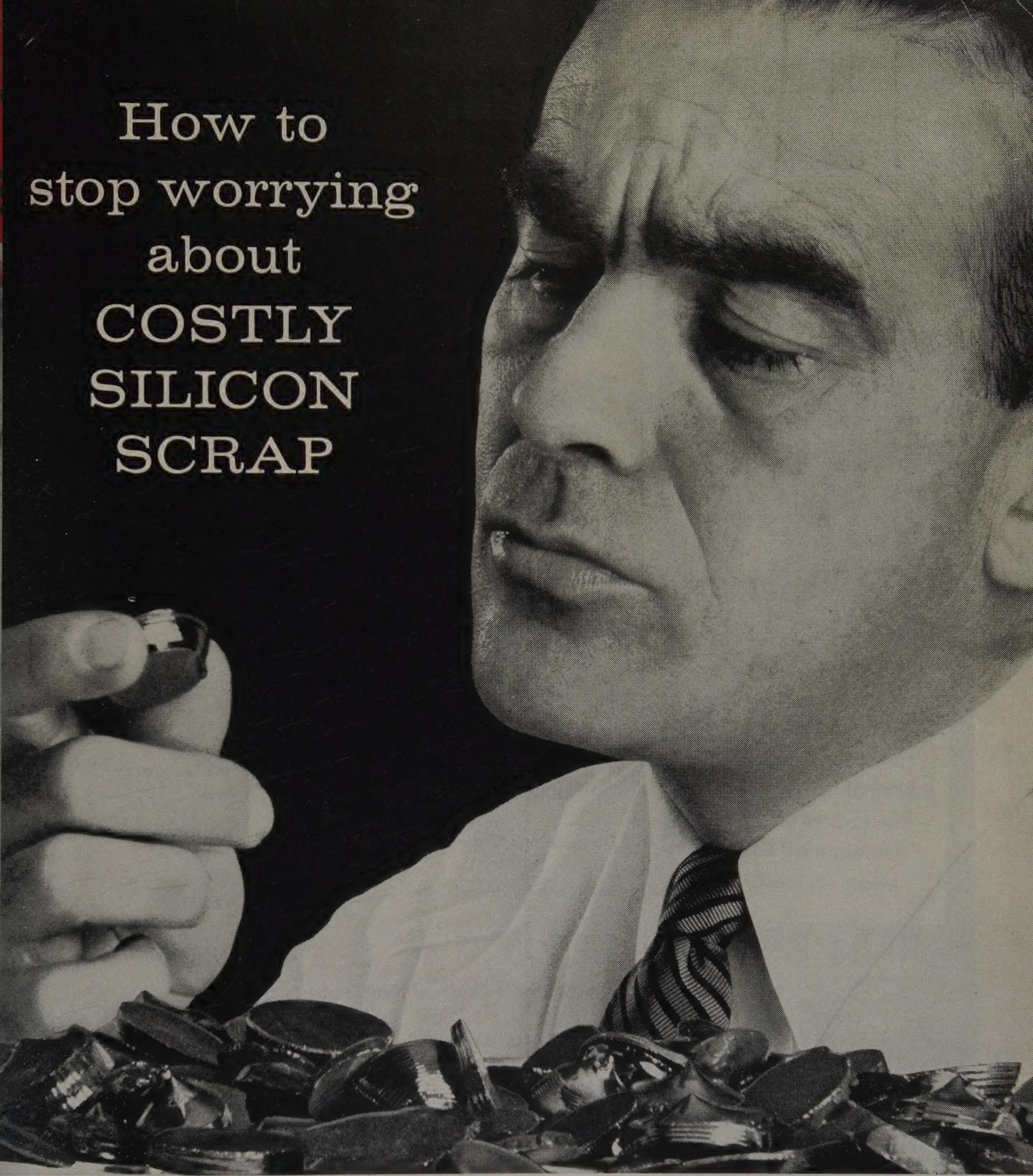
* Sessions terminate at 12:00 Noon.

Visit Us At The Coliseum—Booth 4215

Design Notes on VHF Tuner

AC Amplifier with High Input Impedance

Hypersensitive Voltage Variable Capacitor


How to
stop worrying
about
COSTLY
SILICON
SCRAP

SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

March 1960 Vol. 3 No. 3

CONTENTS

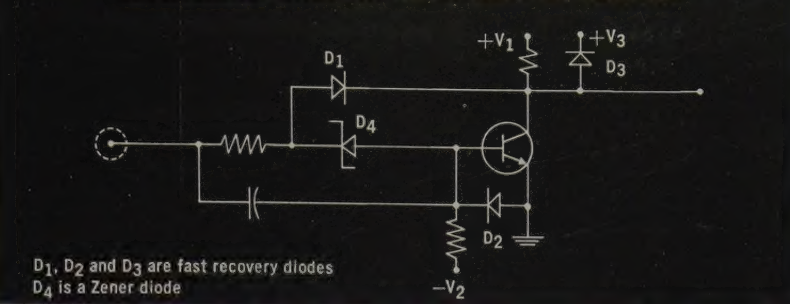
Front Cover

Technical Program—1960 IRE International Convention—New York City Coliseum and Waldorf-Astoria Hotel, March 21-24.

(SEMICONDUCTOR PRODUCTS' Exhibit is at Booth #4215—New York Coliseum.)

RELIABLE SILICON TRANSISTOR SWITCHING

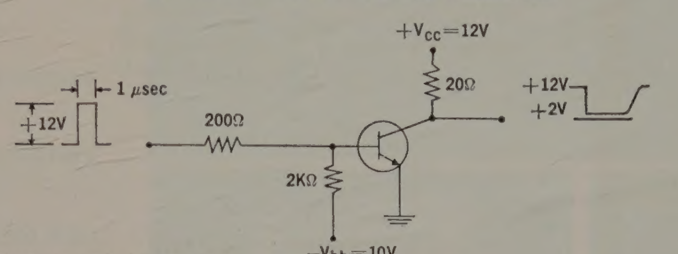
NON-SATURATED SWITCH WITH LONG-STORAGE-TIME TRANSISTOR



D_1, D_2 and D_3 are fast recovery diodes
D_4 is a Zener diode

9 COMPONENTS REPLACED BY 4

SATURATED SWITCH WITH 2N1252 TRANSISTOR



Collector current: 0.5 ampere
Typical switching time: t_d=20mµs., t_r=60mµs., t_s=30mµs., t_f=40mµs.

HOW? — By using Fairchild's 2N1252 or 2N1253 **lowstorage** silicon mesa transistors. The guaranteed low storage characteristic permits a simple saturating circuit to achieve switching speeds that previously required complex non-saturating circuits.

WHY? — Improved reliability and reduced cost — one semiconductor instead of five and fewer soldered connections. Power dissipation is only 1/3rd to 1/5th as great, making possible much higher component densities in packaging. Cost and reliability are improved all the way from development through volume production.

WHERE? — Switching circuits in general. The 2N1252 and 2N1253 are ideally suited to high-speed high-current switching applications such as magnetic-core drivers, drum and tape write drivers, high-current pulse generators and clock amplifiers. In addition, the transistors are applicable to medium-speed saturated logic circuits.

FAIRCHILD 2N1252 and 2N1253

Symbol	Characteristic	Rating	Min	Typ	Max	Test Conditions
h_{FE}	D.C. pulse current gain 2N1252		15	35	45	I_C=150mA V_C=10V
	2N1253		30	45	90	
P_C	Total dissipation at 25°C case temperature	2 watts				
$V_{BE\ SAT.}$	Base saturation voltage			0.9V	1.3V	I_C=150mA I_B=15mA
$V_{CE\ SAT.}$	Collector saturation voltage			0.6V	1.5V	I_C=150mA I_B=15mA
h_{fe}	Small signal current gain at f=20mc 2N1252		2	4		I_C=50mA V_C=10V
	2N1253		2.5	5.5		
I_{CBO}	Collector cutoff current			0.1µA	10µA	V_C=20V T=25°C
				100µA	600µA	V_C=20V T=150°C
t_s+t_f	Turn off time			75mµs	150mµs	I_C=150mA I_{B1}=15mA I_{B2}=5mA R_L=40Ω Pulse width=10ms

For full specifications, write Dept. D-3   See us at Booth #2701-3-5-7 on the second floor at I.R.E.

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Semiconductor Products

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MINIATURE

SELENIUM RECTIFIER BRIDGE

Excitingly New!

another achievement of General Instrument Corporation

the industry's most practical package

reduced to 1/10 conventional size . . . and priced as low as 63¢!

Here is the most convenient and reliable selenium bridge ever made. Check it over feature by feature and you'll see why . . .

SIZE 13/16" x 7/8" x 15/32" making it the smallest bridge available—1/5 to 1/10 the size of conventional devices.

PACKAGE Flat, compact and incredibly sturdy, it has a twist-on lug for solid and simple mounting.

RELIABILITY The selenium cells have no artificial barrier layer thereby reducing aging and high voltage drop.

VERSATILITY Designed to operate off line voltage, the bridge is rated at 155V rms max., 90 ma D.C. Size, shape and dependability make it ideal for many commercial applications.

PRICE Only 63¢ in production quantities, the bridge is practical for many types of equipment where half-wave circuits are now used.

Further technical data is available upon request to Section

Visit us at the IRE Show, Booths 1218-24

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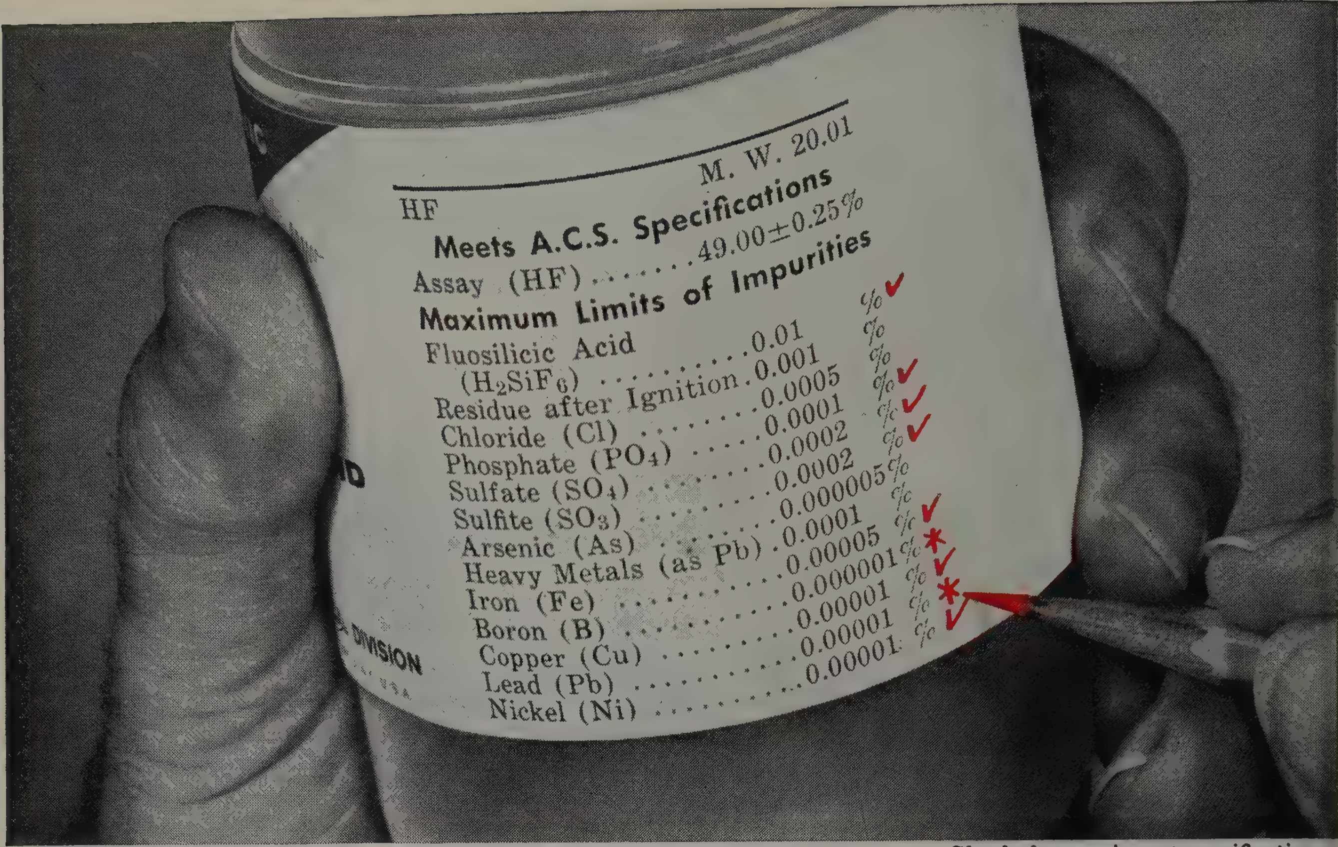

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For years, Baker & Adamson's "Electronic Grade" Hydrofluoric Acid has been the purest available. Now, to serve electronic requirements even better, this high purity has been still further improved.

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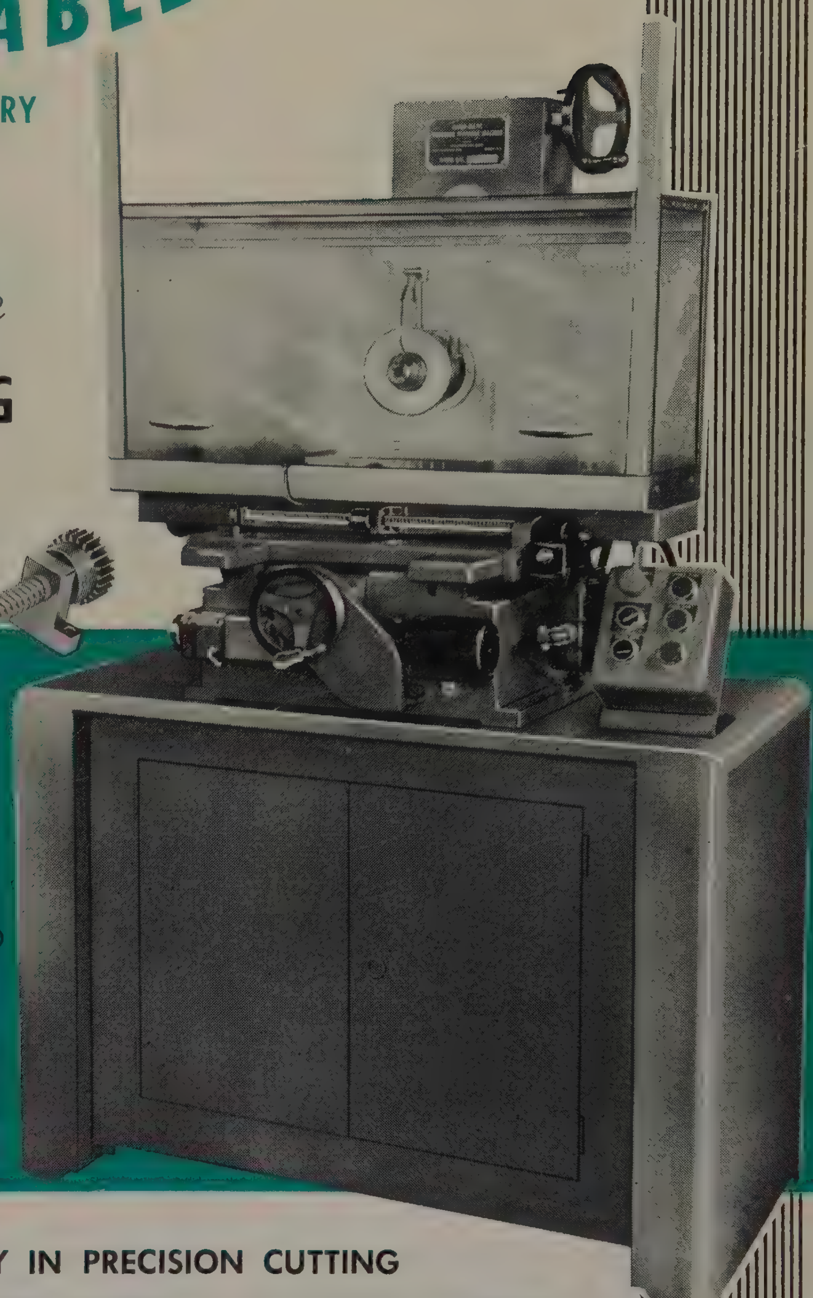

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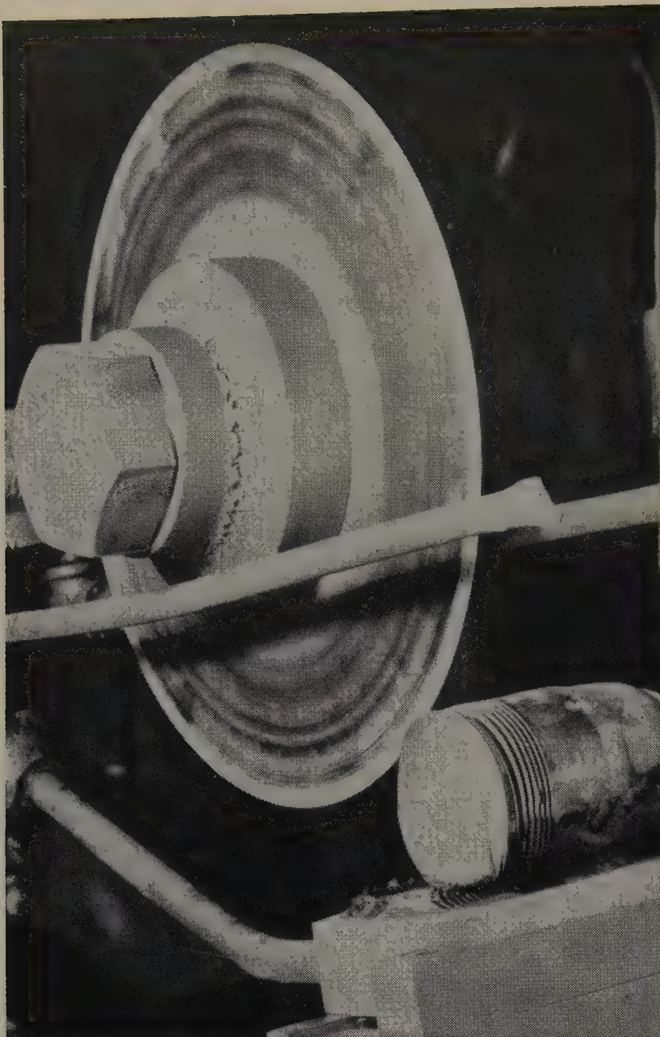
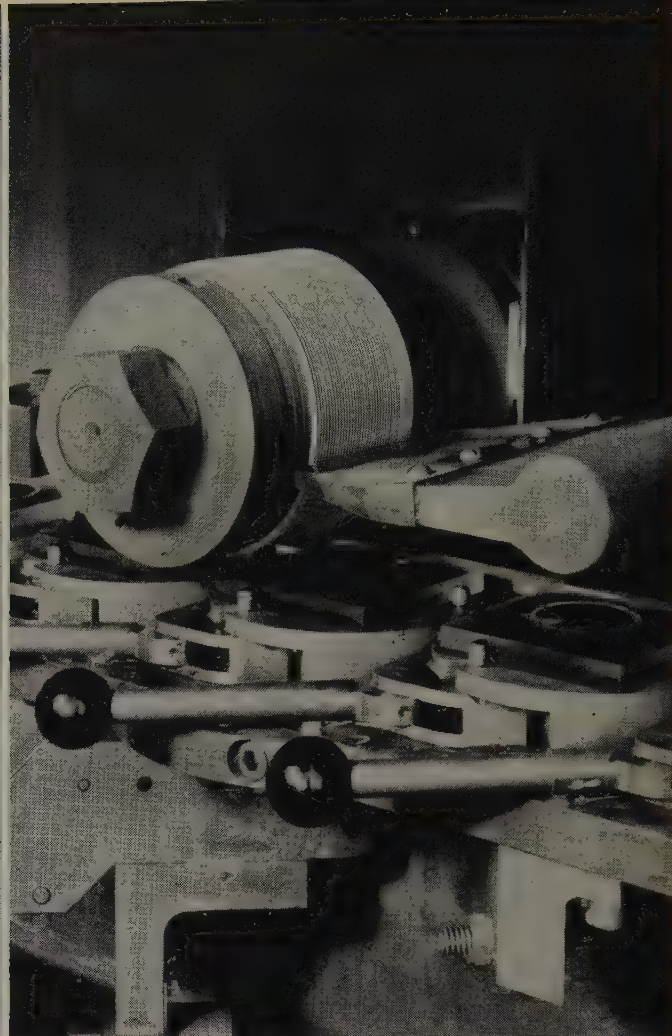
SEE IT AT THE IRE SHOW BOOTH 4038





Slicing and dicing operations are both performed by Norton diamond cut-off wheels. An ingot of pure silicon, cemented to a ceramic block is sliced by a single wheel. In dicing, wafers are also mounted on ceramic blocks. Ganged wheels first cut in one direction; then the blocks supporting the wafers are turned 90° for the second cut. The tiny diced pellets, used in diodes, are about 1/32″ square by .020″ thick. (Photos courtesy of Hughes Aircraft Company).

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These Norton diamond wheels always cut fast, free and straight. Their extreme thinness and non-chipping action avoids wasting valuable material. And their dimensions are constantly uniform as specified — especially important when wheels are set up for gang dicing.

Remember: Norton was first to introduce all three types of diamond wheels — resinoid, metal and vitrified bonded . . . does all its own checking and sizing of diamonds . . . certifies the diamond content . . . duplicates wheel specifications with consistent accuracy . . . brings you a complete line, covering every application.

See your Abrasive Engineer or Norton Distributor for prompt service and additional facts. Or write to NORTON COMPANY, General Offices, Worcester 6, Massachusetts. Plants and distributors around the world.

Diamond-hard, yet paper-thin. Miking of this Norton diamond cut-off wheel shows an extreme thinness of .004″ — a typical result of Norton leadership in developing diamond wheels "tailor-made" to every application for finest results.

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2N696 2N697 2N699 2N706

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HIGHER POWER 2N706 provides sophisticated logic device of even greater value for reliable high-speed operation in the saturated region.

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ELECTRICAL CHARACTERISTICS (25°C)

Type	2N696	2N697	2N699	2N706
V_{CBO}	60v.	60v.	120v.	25v.
h_{FE}(Min.) (I_C=150ma, V_{CE}=10V)	20	40	40	15
h_{fe}(Min.) (I_C=50ma, V_{CE}=10V, f=20mc.*) for 2N706: f=100mc.	2.0	2.5	2.5	2.0
P at 25°C case temp.	2w.	2w.	2w.	1w.

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SPERRY

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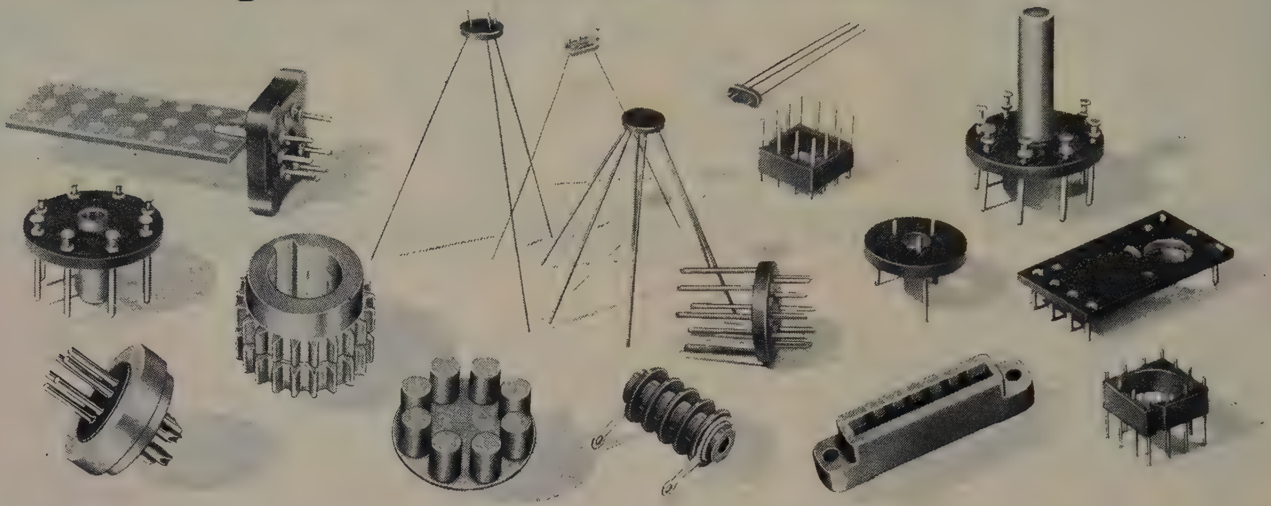
CUSTOM MOLDING OF EPOXY SUB-COMPONENTS

...terminal boards, connectors, pin blocks, shift registers, headers, with or without inserts!

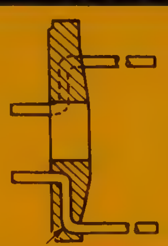


Epoxy Products, originator of the famous all-epoxy E-Pak encapsulation system, now offers its wide experience and equipment for the custom-molding of specialized epoxy sub-components. These sub-components can be molded with a wide variety of inserts (produced in our own precision metal working facilities) to fit your particular requirements. Every unit is delivered in finished form, tested and ready for reliable use with your component.

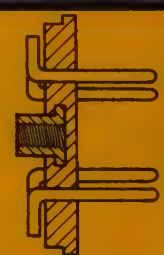
Let us design to meet your special requirements, in all materials including fire resistant and colored epoxy compounds. Write today for further information.

Here are 4 versions of custom-molded, all-epoxy sub-components

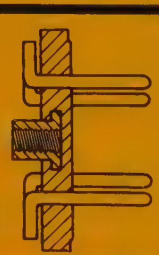
In addition to conventional "straight through" leads, headers can be designed where the leads take a bend through the body of the header.



Headers have been made with shoulder ridge that is molded to fit into and support the case. A threaded brass insert may also be molded into the header to fit the female end of the component.



Dissimilar leads may be welded together so that the bond between them can be molded into the header for additional strength.



Header leads are embedded to fit a standard seven-pin miniature socket. A wide choice of epoxy formulations, for use with copper, brass, silver, gold-plated metals, etc., is available.

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Book Reviews

TITLE: Vacuum-Tube & Semiconductor Electronics

AUTHOR: Jacob Millman

PUBLISHER: McGraw-Hill, New York

Vacuum-Tube and Semiconductor Electronics is a book written to be used as a college undergraduate textbook, for a first electronics course, presenting an integrated view of modern electronics in terms of both transistors and vacuum tubes.

The book starts by developing the concept of motion of charged particles in magnetic and electric fields. The concepts are evolved from the physics and numerous illustrations and examples do much to clarify the work. The application of theory is made in chapter II, where the cathode-ray tube is covered in detail by considering the magnetic and electrostatic deflection conditions.

Chapter III introduces metals and semiconductors from an atomic concept. Again the liberal use of illustrative material aids in understanding. Thermionic emission is included as preface to the next two chapters which treat the vacuum and semiconductor diodes.

Chapters VIII and IX proceed in a like manner. Chapter VIII is a very concise presentation of the vacuum-triode. Both the Thévenin and Norton equivalent circuits are used to explain circuit operation. Many circuit configurations are discussed and each circuit is analyzed in detail. Chapter IX introduces the junction transistors characteristics in a like manner. Here again a very thorough presentation is made. The actual operation of the transistor merits a separate chapter in itself which is entitled "Transistor Linear Equivalent Circuits". The familiar transistor circuit configurations are derived for both the T and h-parameter equivalents.

The balance of the book covers many additional topics such as rectifiers, discharge in gases, untuned voltage amplifiers, feedback amplifiers, oscillators and power supplies. The solution of Poisson's equation and the development of the continuity equations for a semiconductor are to be found in a very extensive appendix.

Vacuum-Tube and Semiconductor Electronics is an excellent book, rare in its clarity of presentation and scope of coverage. Even those well schooled in the field of electronics would do well to add this definitive work to their bookshelves as a basic textbook and reference of very useful information.

TITLE: Television Engineering, Principles and Practice (Volume IV)

AUTHORS: S. W. Amos, D. C. Birkinshaw

PUBLISHER: Iliffe & Sons Ltd., London

Television Engineering, Principles and Practice is the fourth volume in a series of training manuals used by the British Broadcasting Corporation.

The first chapter discusses counter circuits starting with basic definitions and circuits. The step counter or storage capacitor is described and the discussion leads to the use of the divider or a method of frequency division. The ring counter and binary counter are next considered and again methods of frequency division are shown. The material leads quite smoothly into the second chapter entitled "Frequency Dividers". The methods of frequency division are very thoroughly treated in terms of the requirements of television.

Chapters III, IV and V discuss the *d-c* clamp and restorer in very great detail. Chapter III draws the distinction between these two circuits and goes on to describe the requirements and limitations of both. Chapter four is devoted entirely to the restorer and chapter five to the clamp.

A topic rarely treated in adequate detail, gamma, is next considered in the sixth chapter. Gamma, or the slope of the curve of log output versus log input, is a basic television quantity since it is indicative of the tonal qualities of the television picture. This chapter discusses the effects of extremes of gamma and describes special circuitry to achieve gamma control. Various gamma corrector circuits are described utilizing non-linear vacuum tube characteristics as the gamma correcting device.

The balance of the book covers delay lines, equalizers, line and field output stages as well as regulated cathode followers and amplifiers in addition to other selected topics.

Television Engineering is more than an excellent textbook, it is a practical engineering manual of theory, circuits and techniques. The material is presented in an unusually understandable form by authors that obviously know their engineering. This coupled with the value of the material itself should place this book well in the library of the television engineer and technician.

By Stephen E. Lipsky

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for ultra-precision slicing and dicing of semiconductor materials

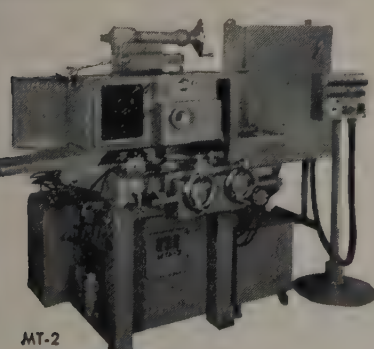
Large silicon crystal being wafered on an MTA-7. Wafers .030″ thick are being cut at 1 sq. in. per min. with parallelism between .001″ and .002″.

Today more than 60% of all transistor elements are being cut on Microtom-atic machines. This industry-wide preference was won through sheer performance — dependable accuracy, high production rates, and trouble-free, continuous-duty operation.

Now the new Microtom-atic MTA-7 brings even greater accuracy and increased production at lower cost. Unique cross-feed mechanism co-ordinates mechanical and hydraulic movements to achieve ultra-precision indexing. Fracture-free cutting of extremely thin wafers with excellent parallelism is no problem on the MTA-7. Simple, accurate controls expedite setup with minimum waste and then the MTA-7 automatically repeats the indexing and cutting cycle until the crystal is completely sliced.

The new MTA-7 is extremely rigid throughout with heavy base, saddle, table and column construction. Long life and continued accuracy are assured through generous bearing areas, hand-scraped ways and positive, automatic lubrication of all contact areas and lead screws.

If your work involves slicing of hard, brittle and shock-sensitive materials, DoALL can help you. Call your local DoALL Sales-Service Store and discuss your problem. A corps of specialists and the DoALL Demonstration Test-Center are at your disposal.



MT-2

Model MTA-7 provides index stroke from 0 to .100″ per index with positive table rates as low as 1/16″ per minute. Other models available.

DoALL diamond slicing wheels are produced by an exclusive process that insures positive rim bond to the core. These wheels deliver extreme accuracy . . . save time and materials.

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A SIGNIFICANT PROFESSIONAL CAREER ANNOUNCEMENT TO SEMICONDUCTOR ENGINEERS, CHEMISTS and PHYSICAL CHEMISTS . . .

CBS ELECTRONICS*

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NEW MADT PROGRAM

THE PROGRAM . . . This is a major long range program in the mass production of Micro Alloy Diffused-base Transistors (FAST SWITCHES, HF AMPLIFIERS and HF POWER OSCILLATORS) through the use of electro-chemical jet etching and plating. These high-frequency transistors with extreme accuracy and uniformity for use in industrial and military computers are acknowledged to be the most challenging phase of *tomorrow's* data processing systems.

THE OPPORTUNITY . . . Engineers, Chemists and Physical Chemists with competence in semiconductors can now apply their full technical capabilities on CBS Electronics' new MADT program which offers exceptional ground-floor opportunities. Positions are available at all levels. Degree in one of the physical sciences required.

*THE COMPANY . . . CBS ELECTRONICS is the engineering and manufacturing arm of COLUMBIA BROADCASTING SYSTEM, Inc. Supported by its full resources and under engineering-oriented management, we continue our sound expansion . . . with products characterized by ultra-high quality to meet the most exacting reliability standards.

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Qualified applicants are invited to send resume to Mr. H. C. Laur. In replying, kindly designate Dept. 2927.

ELECTRON TUBES
CBS
SEMICONDUCTORS

CBS ELECTRONICS

A Division of Columbia Broadcasting System, Inc.

900 Chelmsford Street, Lowell, Mass.


4NAE

Personnel Notes

Morgan E. McMahon has been appointed manager of the engineering department of Pacific Semiconductors, Inc., to succeed R. A. Campbell, who was recently elected vice president in charge of operations, Dr. Harper Q. North, president, announced. Mr. McMahon, who has been serving as manager of product engineering, will be responsible for over-all engineering department activities, with special emphasis on the company transistor program. At the same time, Dr. North announced the appointment of Elmo E. Maiden, manager of special products, as assistant manager of the engineering department with special responsibility for the PSI micro-electronics program and the establishment of the Micro-Diode Plant.

George E. Stoll and A. P. Fontaine have been elected executive vice presidents of the Bendix Aviation Corporation, it was announced by Malcolm P. Ferguson, president. They both are directors of the corporation and members of its administration committee and served previously as vice presidents and group executives. Mr. Stoll will be responsible for the direction of 24 U.S. divisions and subsidiaries. He plans to move his headquarters from South Bend, Ind. to Detroit. Mr. Fontaine will be responsible for many staff functions, including engineering and research, sales, planning, product development, and patent activities. His office is in Detroit.

Two Philco Research Division executives have been promoted to new assignments, it was announced by Director of Research Donald G. Fink. Allen C. Munster was named Director of Research, Plans and Programs, the division's senior staff position. Lawton M. Hartman, formerly manager of special projects for Government and Industrial Research was appointed Manager, Technical Planning for the Research Division, with responsibility for coordination of broad planning for management and administration.

Dr. Oskar E. Mattiat, well-known authority in the acoustics field, has been appointed Chief Scientist of Acoustica Associates, Inc., of Plainview, N. Y., and Los Angeles, it was announced in Plainview, N. Y., by Robert L. Rod, President. Dr. Mattiat, who received his Ph.D. in Germany, has been engaged in the development of acoustic systems and piezoelectric devices since 1934. At Acoustica, which manufactures ultrasonic cleaning, gaging and processing systems, he will be responsible for all developments in the fields of piezoelectric and magnetostrictive ceramic materials.

Recently appointed Chief Physicist at Semimetals, Inc., is Thomas J. Carroll, formerly with Philco. Mr. Morton Brozinsky, President of Semimetals, said he expected Mr. Carroll's extensive research into semiconductor crystals and other metallics to be of great value to the firm. Semimetals, Inc., is a prime producer of germanium for semiconductor and IR devices, and is located in Richmond Hill, New York. A graduate of Villanova, Mr. Carroll was with Philco for 9 years in metals R&D.

The appointment of Norman L. Stone as Chief Electronic Engineer has been announced by Transistor Specialties, Inc., Plainview, L. I., N. Y. In this post Mr. Stone will direct electronic engineering activities both for the Components and Systems Division and will administer the company's program of product development in the electronic instruments and control fields. He was graduated from Lehigh University with a B.S. degree in Electrical Engineering. He also is licensed as a professional engineer in New York State.

Frank H. Bower has joined the Semiconductor Division of Sylvania Electric Products Inc. as engineering administrator, it has been announced by Dr. J. Earl Thomas, director of research and engineering for the division. In his new post, Mr. Bower is responsible for coordinating the administrative activities of the division's general engineering department. Before joining Sylvania, he was with the Semiconductor Products Division of Motorola, Inc.

International Business Machines Corporation announced that Dr. Leo Esaki, discoverer of the Esaki diode, has joined IBM as a resident consultant. He will work with the Semiconductor Research Department at Poughkeepsie where much of the company's Esaki diode investigative work is being carried out. Dr. Esaki holds the Japanese equivalent of the B.S., M.S. and Ph.D. degrees in Physics from the University of Tokyo and is a member of The Physical Society of Japan. He has been granted a leave of absence from the Sony Corporation in Tokyo where he was in charge of semiconductor research.

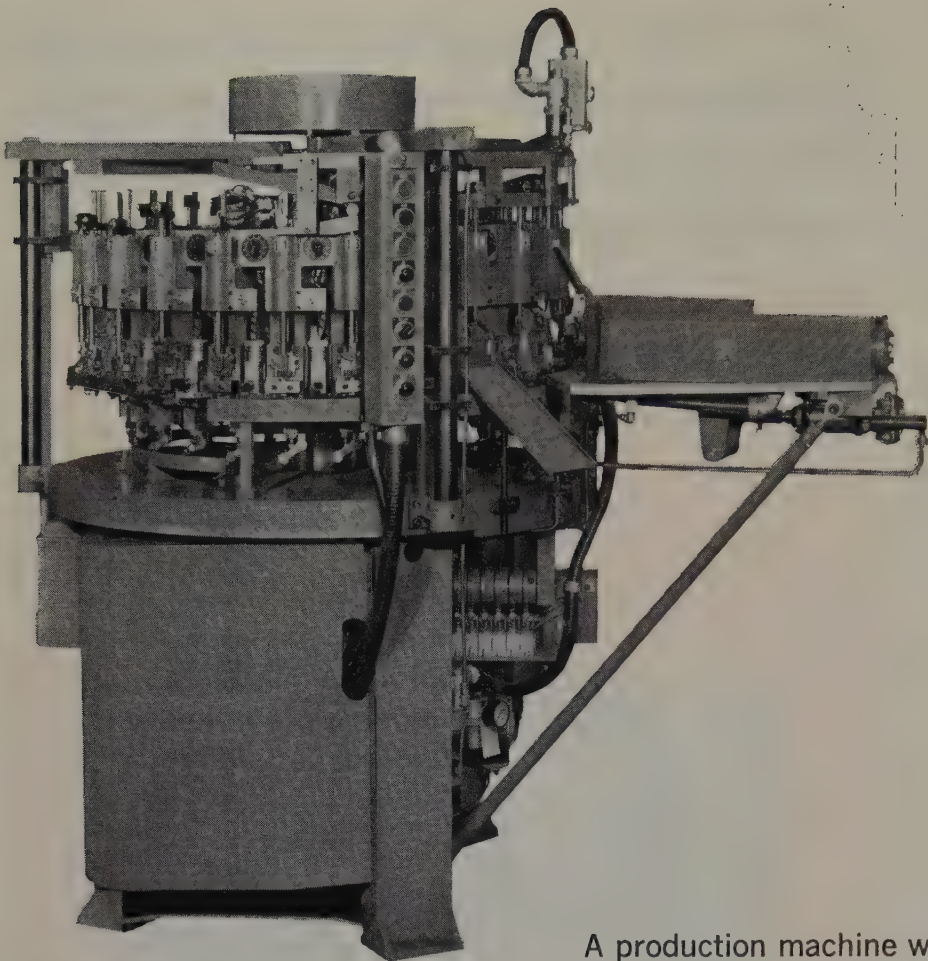
Three appointments to the staff of the Marketing Department of the RCA Semiconductor and Materials Division were announced by T. R. Hays, Manager. Frank F. Neuner, formerly responsible for product planning and associated services, has been named Manager, Product Distribution and Control. Erwin B. May, previously Manager of Promotion, has been appointed Manager, Advertising and Sales Promotion. Irving H. Von Zelowitz, formerly Manager, Sales Coordination, becomes Manager, Semiconductor Planning.

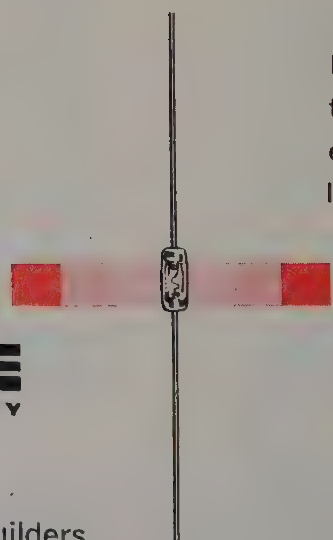
Fred Horowitz has joined U. S. Transistor Corp. as Development and Project Engineer, it was announced by Dr. George Wertwijn, Chief Engineer. A solid state physicist, he was formerly with the Zenith Corp. in Chicago. He is a graduate of the University of Illinois. At U. S. Transistor Corp.'s new plant in Syosset, Long Island, he will concentrate on expanding the Research and Development program.

General Electric has promoted Arling Woolaver to transistor product sales manager in the Semiconductor Products Department. Mr. Woolaver's office is now at the Department's marketing headquarters at the Charles Building, Liverpool, N. Y. In his new position, he replaces C. J. Goodman who was recently appointed eastern regional sales manager for the Department.

Appointment of James R. Fisher as product specialist on piezoelectric ceramic materials for the Sprague Electric Company was announced by Carroll G. Killen, manager of Field Engineering. Mr. Fisher comes to Sprague from the

(Continued on page 94)





Editorial . . .

The 1960 Solid State Circuits Conference

Applications of tunnel diodes, of transistors, of magnetic devices and of parametric amplifiers were the principal topics discussed at the 1960 Solid State Circuits Conference.

As amplifiers the tunnel diodes possess a very low noise figure (less than 4 *db*) which appears to be independent of frequency. Their gain may be made large, but is very sensitive to load, bias supply and temperature variations. Narrow band amplification up to frequencies of the order of 8 *kmc* has been obtained. For this purpose the diode capacitance, which is a function of bias voltage, must be tuned out with appropriate shunt inductive reactance. In particular, very high frequency operation is obtainable by building the diodes as small spots or as narrow strips, and placing them in appropriate cavities.

In addition to the value of the capacitance, limiting factors for high frequency operation are the intrinsic inductance and the series resistance of the terminals.

More reliable operation is perhaps obtained when the diode is used as an oscillator. Simple relaxation oscillators are obtained by biasing the diode in the negative resistance region and series connecting an inductance with very low resistance. In particular the latter circuit, extended to two diodes, lends itself to form flip-flops which may be used for logic operations as bistable, monostable or clock powered units. In the bistable mode, propagation delays of the order of 20 millimicroseconds and rise times of the order of 4 millimicroseconds were mentioned as typical. *AND* and *OR* operations, however, were obtained, respectively, by linear summation and by threshold detection and were highly dependent on the value of the peak current of the diode characteristic. The clock pulse mode, which utilizes a majority decision logic, appears to hold promise of fast and simple operation.

Transistors of the *mesa* type having dimensions of the order of the diameter of a human hair have been built. These are coaxially encapsulated, possess a base diffusion depth of the order of 0.5 μ, a base to emitter capacitance of the order of 1.6 $\mu\mu f$, and input and output impedances of the order of 50 ohms. In particular their use in a transmission line video amplifier having shunt feedback was described. A three stage amplifier with a cutoff frequency of 750 *mc*, a gain of 17 *db*, a noise figure of the order of 5.5 *db*, and an output power of the order of 1 *mw* was discussed.

Transistor logic circuits using current switching techniques and combining diode logic at the base of the input transistor, were shown to provide economy of components and fast output rise and fall times.

In the field of magnetic devices an X band ferrite switch with a switching time 1 μsec and an isolation 30 *db* was presented. On the other hand very thin magnetic films (1000 A°) were shown to be much faster than ferrite cores and to lend themselves to operation of clock pulse type (majority decision) or of domain propagation type.

Parametric amplifiers using tunnel diodes biased in the positive conductance region were shown to present low noise when used as down converters. In a particular application, a pump frequency of 240 *mc*, a signal frequency of 210 *mc* and an output frequency of *30* mc were used, with a resulting power gain of 6 to 20 *db*, corresponding bandwidths of 0.9 to 0.15 *mc*, and corresponding noise figures of 5.5-2.8 *db*. Other parametric amplifier applications discussed use of subharmonic pumping and design considerations of a backward traveling wave amplifier.

Samuel L. Marshall

NEW *from* Penfield

For Semiconductor and Transistor Manufacture

Pressure Cartridge Deionizer Delivers 18-22 megohm Water at Point of Use

The Penfield PM-8 is a monobed deionizer that "polishes" ultra-high purity make-up and rinse water at point of use. Unique design of top distributor and collector well permits flows up to 50 GPH at less than 4 lb. pressure drop — holds exchange efficiency at 100%. Built entirely of plastic to eliminate metallic contamination. Sump is clear, allowing visual inspection of exchange resins. Cartridge unscrews by hand for easy resin replacement. Unit also can be used as cation exchanger, anion exchanger, water softener, activated carbon filter, oxygen remover or organic scavenger.

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Developed for use in conjunction with multiple installations of Model T-20 and Model PM-8 deionizers, a Penfield Regeneration Bench makes renewal of exhausted resin charges a simple in-plant function. Operator needs only feed resin into unit, form a slurry, then turn master control switch to each cycle — resin separation, regeneration, rinsing and proper re-mixing. Capacity is two cubic feet, cycling time about two hours. Average operating cost, including labor and all material, is less than 30c per cartridge — up to 90% saving over outside service.

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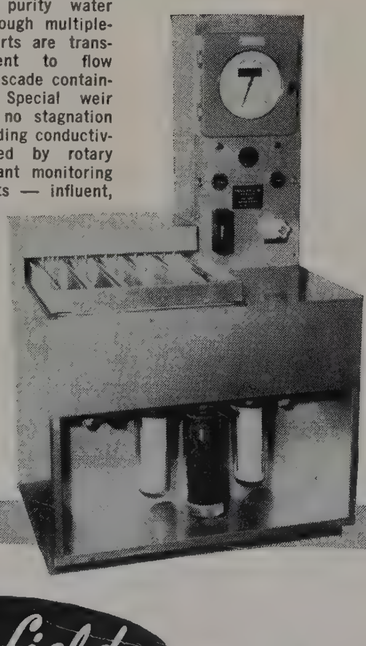

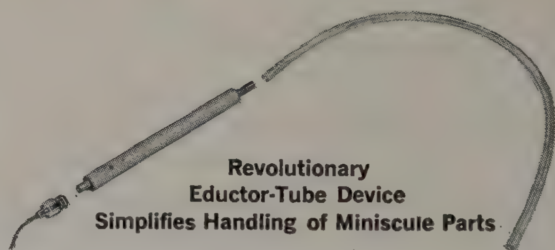

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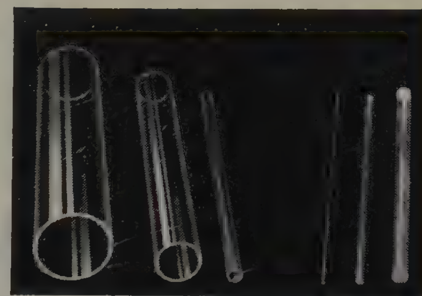

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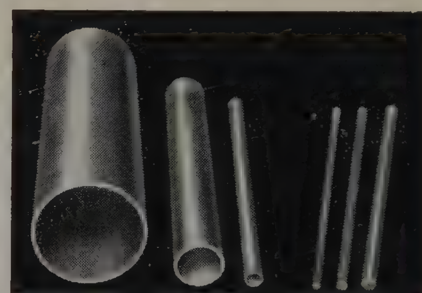

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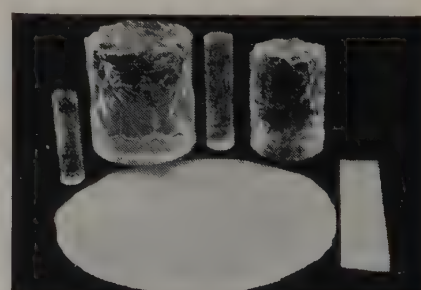

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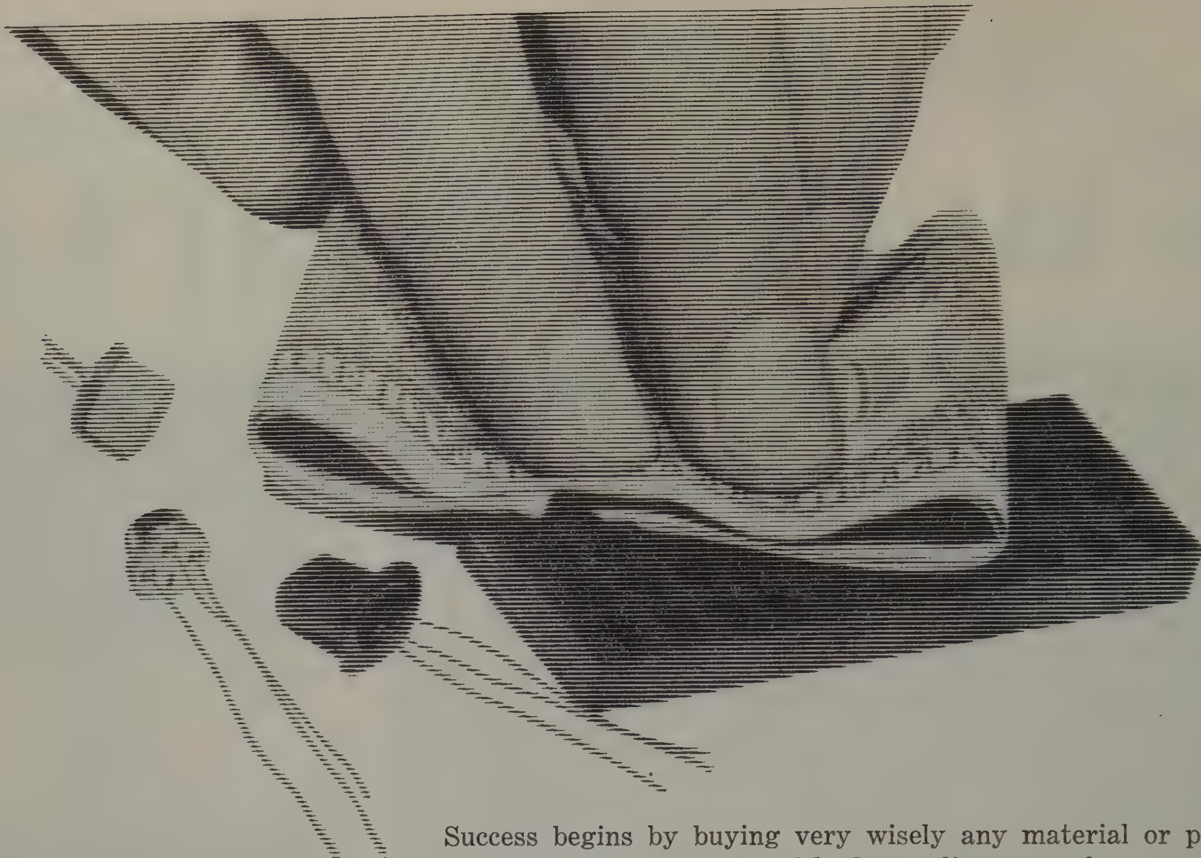

Design Notes on a Transistorized VHF T.V. Tuner

PAUL V. SIMPSON* VICTOR MUKAI**

This article contains notes taken during the design, development, and production of a transistorized vhf television tuner. The tuner employs three *madt* transistors in the conventional *r-f* amplifier, mixer, oscillator arrangement. Data is given to show that noise and gain performance of this tuner is comparable to that of a vacuum tube tuner employing a pentode *r-f* tube. However, the fact is also noted that present transistors, when implemented into the tuner package are capable of noise performance approaching that of the cascode tube.

DEVELOPMENTS IN THE SEMICONDUCTOR field have been extremely rapid; however, it was not until quite recently that high frequency transistors for use in the *vhf* television tuner became commercially available. Such transistors are required to function acceptably in the 50-250 *mc* range in a broad band *r-f* amplifier, mixer, and local oscillator. In addition to this performance requirement the transistors must meet cost and volume production figures as dictated by the entertainment field.

The micro alloy diffused base transistor (*madt*) was one of a few types which showed early promise as a *vhf* device. Another candidate was the mesa transistor which, by its structure, seemed fundamentally strong at high frequencies. However, *vhf* mesa transistor development seemed not as far advanced at the time work was first undertaken to design a commercial transistor tuner.

This paper is essentially a report on a *vhf* television tuner design project using the *madt*. For this project the tuner engineering sections of both the Philco Corporation and the General Instrument Corporation collaborated in order to come up with a commercial design for use in the "Safari," a transistorized battery operated portable television receiver. The project has long since been completed and many thousands of tuners have by now been mass produced. Noise and gain performance of the tuner using the *madt* is comparable to the performance of a vacuum tube tuner employing a pentode *r-f* tube.

The general plan of this presentation is first to consider individual stage operation, that is, operation of the *r-f* amplifier, mixer, and oscillator stages by themselves in their *d-c* and *a-c* aspects. The individual stages are then coupled together into a single channel tuner in order to discuss the associated resonant circuitry. Only channel 13 data is considered in this portion of the paper since at the highest frequency channel the transistor is most severely taxed to perform. A brief description of the completed 12-channel design, the package, and some overall measurements and comments conclude the article. Since a commercial transistor television tuner is as yet relatively new it is felt that the objective within the scope of a single article of a few pages should be broad in subject coverage rather than specifically vigorous.

Some of the illustrations in this article are reproductions of curves taken during our early design work, most of which was done using hand-made *madt*'s. To this extent there may be variations as things stand today, at least in magnitudes, since the tuner development and the transistor development proceeded hand in hand. However, it is believed that the character or trend of the curves is essentially the same.

RF Amplifier: Noise Figure, Gain vs. Operating Point

Fig. 1 shows a plot of gain and *NF* against collector current at constant voltage for a common emitter connected *r-f* stage. Gain and noise figures are, of course, primary performance criteria for the *r-f* stage. Note that from about 2.5 *ma* on, the curves are relatively flat; also that the point for best gain and lowest *NF* almost coincide. This is somewhat different than for a vacuum tube, where best *NF* occurs about 1½ *db* or so beyond best gain.

To an extent these curves may be looked upon as a factor in the determination of operating point for the *r-f* stage since this represents an optimization of important operational criteria against the imposed *d-c* conditions. Of course in the overall consideration of the quiescent point other problems such as collector dissipation may become critical and force a compromise with performance. By and large if you get down to fine details the matter of operating point can be a hazy proposition until many curves have been run. Because of manufacturing difficulties in controlling β, it is of course important to stabilize rather heavily to avoid large variations in production and to enhance interchangeability. The stabilization factor for

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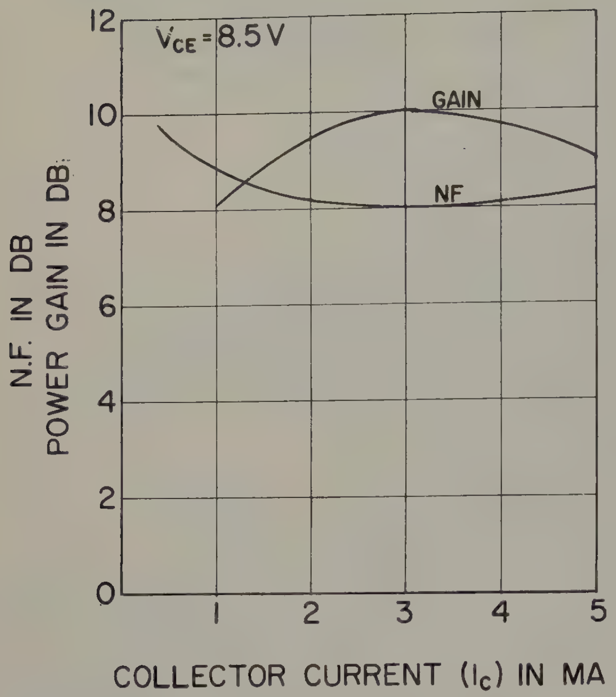

Fig. 1—Noise figure and gain *vs.* collector current for r-f amplifier.

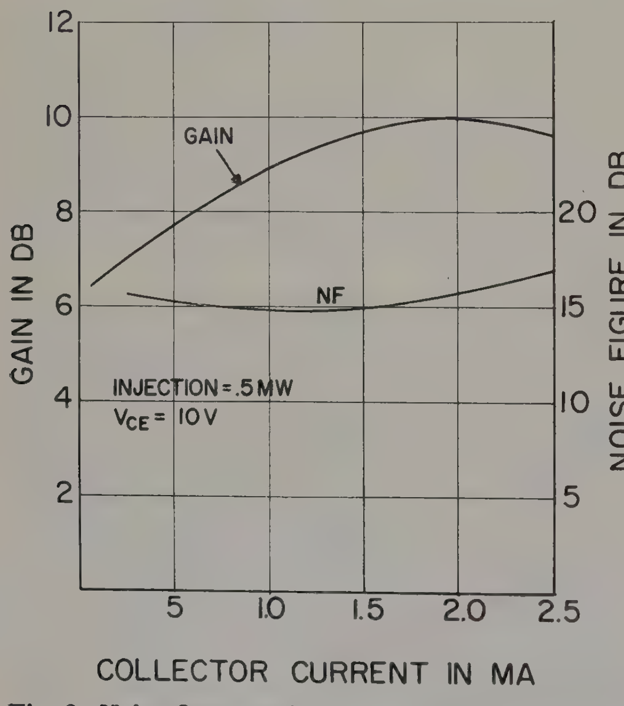

Fig. 2—Noise figure and gain *vs.* collector current for mixer stage.

the *r-f* stage is around 4.5, the collector current in the neighborhood of 3 *ma* at about 7 *V.* collector to emitter voltage. The low input impedance level (in the neighborhood of 50-100 ohms) of the transistor provides considerable design latitude as to the *d-c* biasing network.

A decrease of collector voltage at constant current resulted in lower noise figures. However, gain fall-off is rapid and advantage could not be taken of this property.

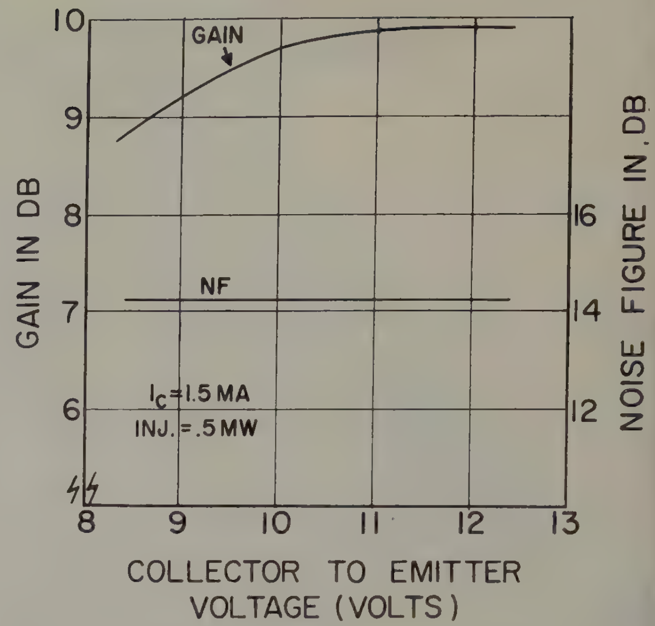

Fig. 3—Gain and noise figure *vs.* V_{ce} (collector to emitter voltage) for mixer stage.

Mixer Stage: Noise Factor, Gain vs. Operating Point

Similar curves are shown in *Fig. 2* for the mixer stage taken at an adequate oscillator injection level. Note that here maximum gain occurs at somewhat beyond the point for lowest noise (about 1.5 *db*). A collector current of approximately 1.5 *ma* seemed to be a reasonable choice for mixer operation.

Fig. 3 is a plot of mixer gain and noise against collector to emitter voltage at 1.5 *ma* of current. The noise figure hardly varied at all here while gain was reasonably flat from approximately 10 *V* and higher.

On the basis of these and other similar curves, a nominal quiescent point of 10 *V* and 1.5 *ma* was selected.

It should be noted that since the given curves of noise are for individual stages only these noise figures must be related to system noise before conclusions can be drawn. At *r-f* stage gain levels, shown in *Fig. 1*, the mixer stage is still contributing to system noise figure. Although gain magnitudes shown on the curves were subject to some experimental error, it was still possible at this point of the design to estimate that 16 *db* of system power gain (70 ohm input and output levels) and a system noise figure of 12 *db* were realistic design targets to shoot for.

Mixer gain and noise figure as related to oscillator injection is shown in *Fig. 4*. Approximately 0.2 volt *rms* of injection is required from the oscillator source on channel 13. This corresponds, typically to 0.5*mw* in injection power needed to optimize mixer gain and noise.

Oscillator Stage: Power vs. Operating Point

Much more than the required .5*mw* of mixer in-

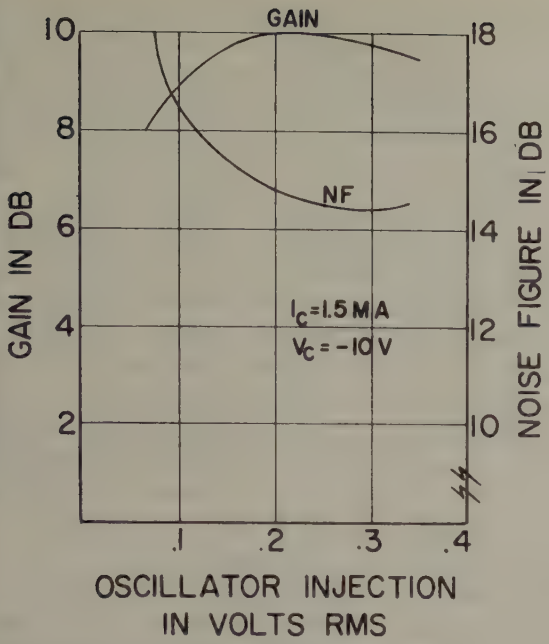

Fig. 4—Gain and noise figure *vs.* oscillator injection. Mixer stage, channel 13.

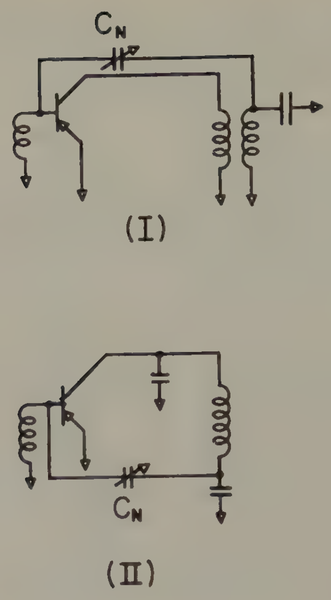

Fig. 5—Types of neutralizing circuits, *r-f* amplifier.

jection power is readily available from the oscillator. The available *a-c* power of course increases with *d-c* input power in the region of operation and varies inversely with temperature. A choice of *d-c* design center for the oscillator stage is therefore a compromise between low line or low battery conditions, temperature rise effects and collector dissipation after injection circuit losses are estimated. Transistor nonuniformity was also considered prior to setting the quiescent point at 8.5 volts and 2.5 *ma.*

Other Factors

There are, of course, many other criteria for each individual stage. For the *r-f* stage there is the matter of neutralization, gain control, and *agc* factors; for the mixer stage, impedance terminations and injection; for the oscillator, the frequency shift (a) with applied *d-c* voltage and (b) with temperature.

For the *r-f* amplifier good neutralization is important for input-output isolation. Two rather familiar neutralizing circuits are shown in *Fig.* 5. Both worked acceptably on a single stage basis as evidenced by the lack of reflections into the input circuit for small transient changes of the output circuit.

Gain control or *agc* is another factor of considerable weight in *r-f* design. Due to the presence of an intrinsic base region in the *madt,* forward *agc* (control of gain by reduced collector voltage) is available as well as reverse *agc* (control by current reduction). A typical curve of both forward and reverse *agc* is shown in *Fig.* 6. As noted in the figure the quiescent point sits on the apex of this curve. A channel 13 gain reduction of about 30 *db* is available in either case.

Of course gain reduction by itself is only a portion of the story on gain control. To be more complete the variations of overload characteristics, picture and sound carrier tilt and v.s.w.r. or impedance should be

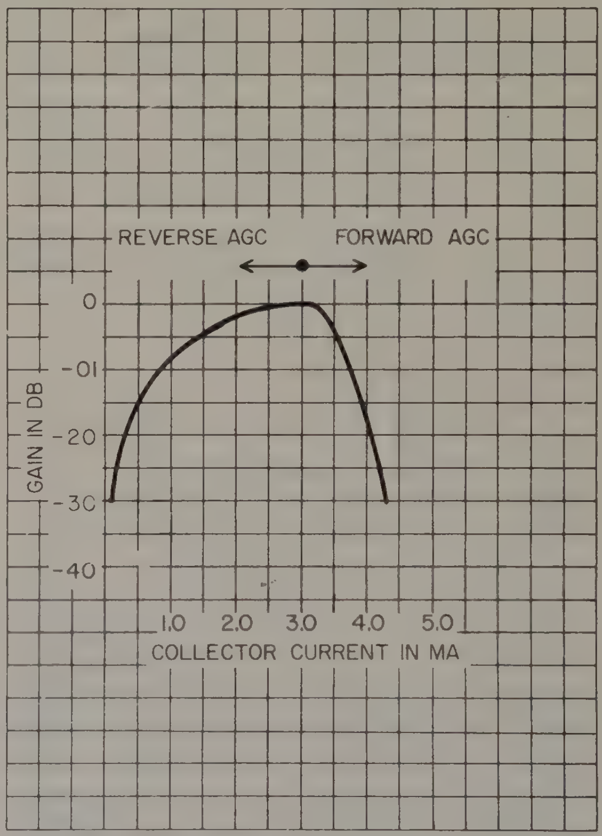

Fig. 6—Gain reduction *vs.* collector current.

evaluated as functions of reduced gain. When such comparisons are made it is seen that the two systems, reverse *agc* and forward *agc,* have a wide difference in the matter of overload level which becomes very small at reduced current. A curve of overload level *vs* collector current depicting this difference is shown in *Fig.* 7. When *agc* bias is such that collector current is near .1 *ma* the open circuit overload voltage of a 300

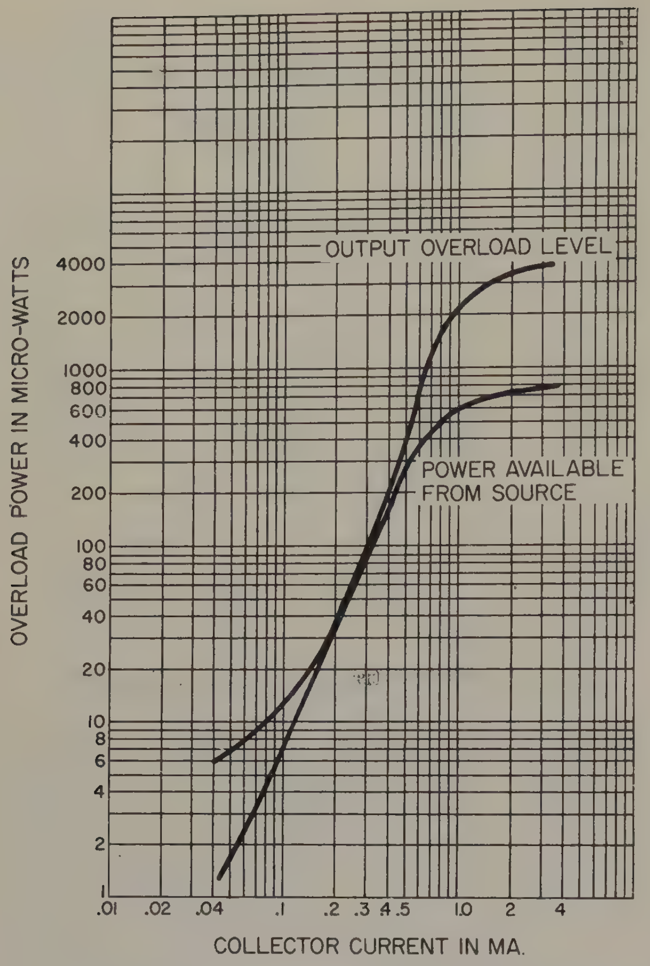

Fig. 7—Overload characteristics of *r-f* amplifier.

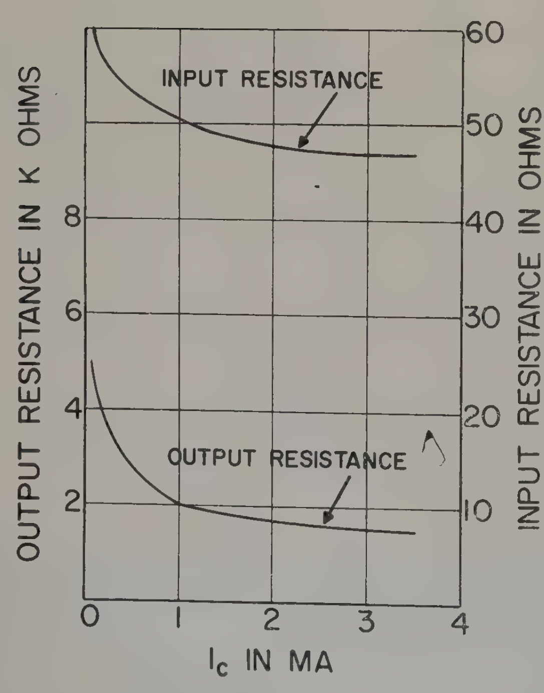

Fig. 8—Input resistance *vs.* I_e, Output resistance *vs.* I_c *r-f* amplifier.

ohm source would be merely 45 *mv*. At zero bias this voltage is in the vicinity of 1 volt although the mixer would probably overload in this case. Particularly for this reason forward *agc* is to be recommended; however, forward *agc* requires a control voltage which is greater than the supply. A manual type gain control in the form of a fringe-suburban-local switch was used to reduce collector voltage for the tuner used in the "Safari" Set. The manual type of gain control can be described as something in between the two other systems of *agc* since current is reduced also, but not nearly as much as in the case of reverse *agc*.

As an illustration of what happens to input and output *R* with current, a curve showing this variation is given in *Fig. 8*. At 3 *ma* of current, input *R* is 50 ohms for this transistor and the output *R* 1500 ohms, but for reduced current values (I_c in the vicinity of < 1 *ma*) the slope is changing rapidly.

Since a mixer contains many frequencies it is of course reasonable to expect that its characteristics at signal frequency can be affected by its external termination at important off signal frequencies such as l.o. frequency, l.o. 2nd harmonic frequency, image frequency and *i-f* frequency. A study of these various terminations revealed that the *i-f* termination from base to ground was by far the most dominant impedance for the common emitter connected mixer. A series resonant circuit connected from base to ground to lower the *i-f* impedance made a difference of about 4 *db* in gain, and 6 *db* in mixer stage noise figure. This is mixer noise alone and is worth about one and a half *db* when considering total system noise. It was also clear that tapping the mixer input onto a low impedance point on the interstage resonant circuit was another way of obtaining low *i-f* input impedance at the mixer. The mixer has at its input a shunt *RC* network amounting to about 7 $\mu\mu f$ in capacity and 70-100 ohms in resistance. The output resistance at 40 *mc* is on the order of 10K ohms. When the mixer impedances are considered together with those for the *r-f* stage it is seen that the available bandwidth is much greater than that required for TV.

Aside from power considerations, the other important oscillator characteristic is frequency shift (a) with voltage and (b) with temperature.

A typical curve of frequency shift with voltage for the oscillator is shown in *Fig. 9*. The frequency rises 250 *kc* at 14 volts V_{cc} and falls about a megacycle at 8.5 volts totaling 1.25 *mc* over a 5.5 *V* range. From the nominal voltage of 12 *V* $\pm$ 2 volts, the shift is
$+ 250$ *kc.*
$- 500$ *kc.*

The tabulation of frequency shift with temperature in *Fig. 10* shows that lower stability factor helps substantially in reducing frequency shift with temperature. "Other Compensations" refer to the application of T.C. capacitors and material changes, techniques common to vacuum tube oscillators. With a stabilization factor of approximately 3, and good materials in the physical support of components, it was possible to

keep short term drift within ±300 *kc* of a one minute warm-up time initial frequency, the rise being 25 degrees C. An average total fine tuning range of 3 to 5 *mc* has been adequate to cover these changes, plus the changes incurred by battery aging.

Single Channel Tests

Fig. 11 is a schematic of the individual stages coupled together into a single channel tuner. Measurements of gain and noise factor taken on a set-up of this kind on channel 13 measured 16-21 *db* in 70 ohm power gain and 10.5 to 12.5 *db* in noise over several sets of transistors. This single channel schematic is also a simplified representation of the tuned circuit line-up in any channel position of the completed tuner.

Design choices as to the resonant circuitry are largely based on previous experience with tuners in general. The overall *r-f* resonant tank line-up is conventional; single tuned input and double tuned interstage, the *i-f* output being taken out at a 70 ohm point on the *i-f* inductance. The 70 ohm antenna output is inductively tapped on the input single tuned circuit while the *r-f* transistor is capacitively tapped. This insures low frequency rejection which is necessary in reducing cross-modulation. The *r-f* collector output operates into a capacitively split tank circuit from which neutralization power is fed back in appropriate phase. The mixer input circuit provides an approximately 6/1 tap down for the transistor and also has low *i-f* impedance to ground by virtue of a series *i-f* tuned resonance circuit which obviates the need to neutralize the mixer. As mentioned before, an alternative circuit in which the transistor is tapped inductively onto the resonant circuit in much the same way that the an-

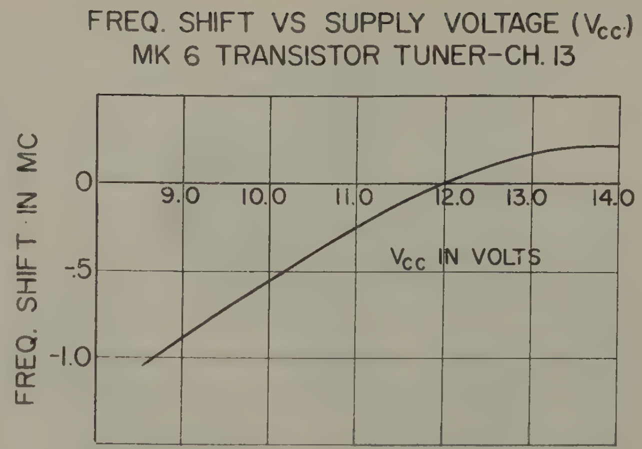

Fig. 9—Frequency shift *vs.* supply voltage of transistor.

FREQ. SHIFT WITH TEMPERATURE	
CONDITIONS	TOTAL SHIFT AT 50°C
STABILITY FACTOR = 6.2	-1300 Kc
STABILITY FACTOR = 3.4	- 500 Kc
STABILITY FACTOR = 3.2 + OTHER COMPENSATION	± 300 Kc

Fig. 10—Frequency shift with temperature.

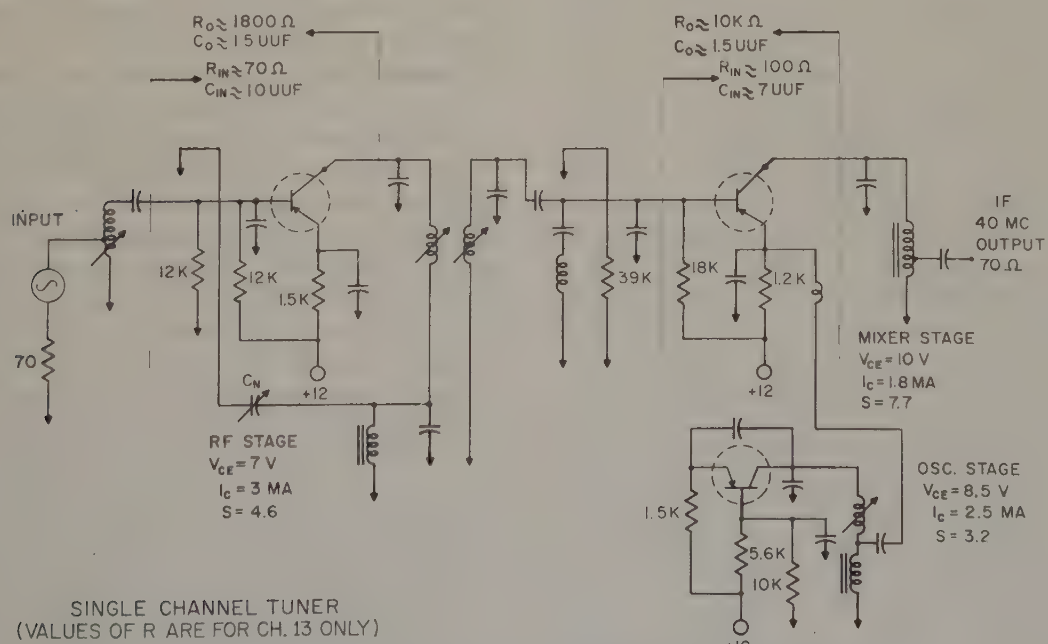

Fig. 11—Single channel schematic—typical impedances shown are for channel 13.

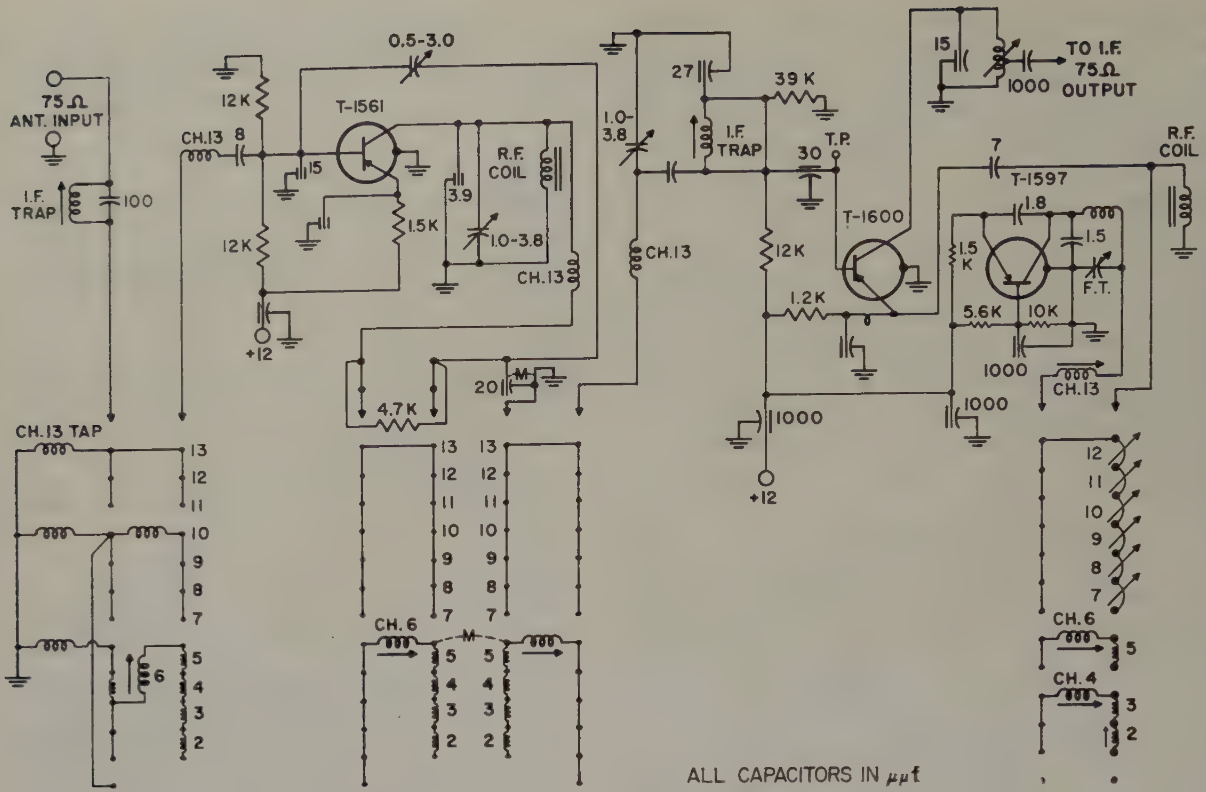

Fig. 12—Schematic of 12 channel TV tuner.

tenna or generator here is tapped onto the input tank can be used. Oscillator power is fed into the mixer with an emitter injection circuit which provides excellent oscillator isolation within the mixer *r-f* passband.

Completed Tuner Package

Completion of the final 12 channel circuitry amounts to tracking the frequency, neutralization, bandwidth, and injection power so as to remain at or near optimum conditions for each channel position with negligible spurious response. Tuner engineers will recognize that this in itself could be a formidable problem particularly with an incremental tuner. However, these are general tuner problems with transistors or tubes and since this is essentially an article on transistorization, this phase will be dismissed here with a few statements with reference to the complete 12 channel schematic of *Fig. 12*. The neutralization of the *r-f* amplifier as viewed backward at the antenna terminals from a signal injected at the mixer input is uniform from channel to channel as evidenced by a distinct dip in output. A considerable reduction of transistor capacity variables is available by the large values of C at both *r-f* and mixer input points. (Note 15 μμf for *r-f* and 30 μμf at mixer.) This minimizes frequency alignment problems caused by transistor variations and replacements. In anticipation of the usual uniformity problems of a new device the control in variations was taken away from the transistors and placed in the components wherever possible. A total of approximately 5 μμf external capacity is also across the *r-f* collector which swamps the transistor capacity by approximately 3:1. Injection power is maintained close to optimum for mixer gain throughout the *vhf* band, while at the same time the oscillator loading on the *r-f* response is minimized by the injection circuit used. The required oscillator power, when measured in terms of *rms* voltage at the emitter, results in lower injection requirements for the low channels (channels 2-6), compared to the high channels (channels 7-13).

The complete circuitry was incorporated into a modified version of the small tuner package shown in *Fig. 13*. This package is 3½″ x 2″ x 2½″ in size. The package had been and still is, used for a tube tuner employing a printed board. With a small amount of retooling, some basic changes were made to produce the transistor package. For the transistor tuner, the printed circuitry was removed for reasons of flexibility in view of the new device. Also for flexibility, sockets were used for the transistor. Components formerly mounted on the printed circuit board were placed above and below the side mounted chassis plate, (this is a sub-assembly as shown), and wired point to point. *Fig. 14* shows the underside of both the sub-assembly and the finished tuner. The overall result is a fairly smooth transition from tube to transistor operation in the same package at reasonable tool cost. Transistors being quite sensitive to environment at these frequencies, the extra shielding resulting from the side mount was helpful in completing the design.

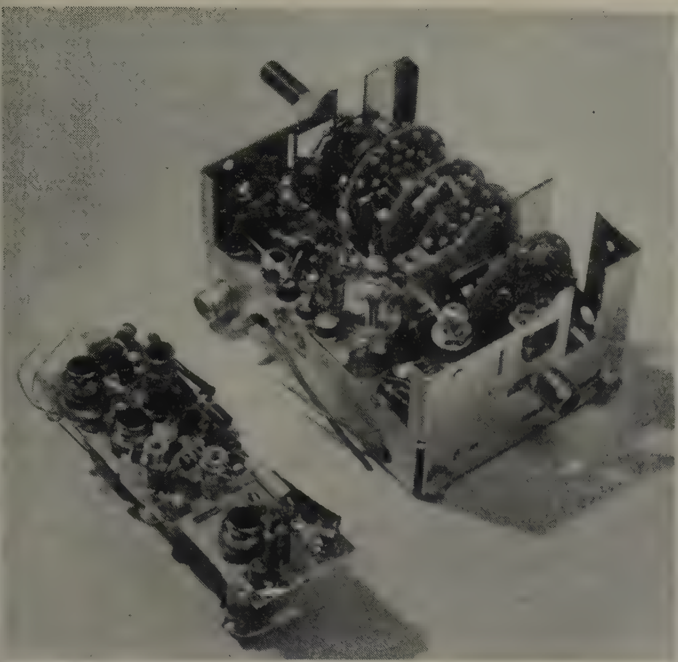

Fig. 13—Modified version of small tuner package.

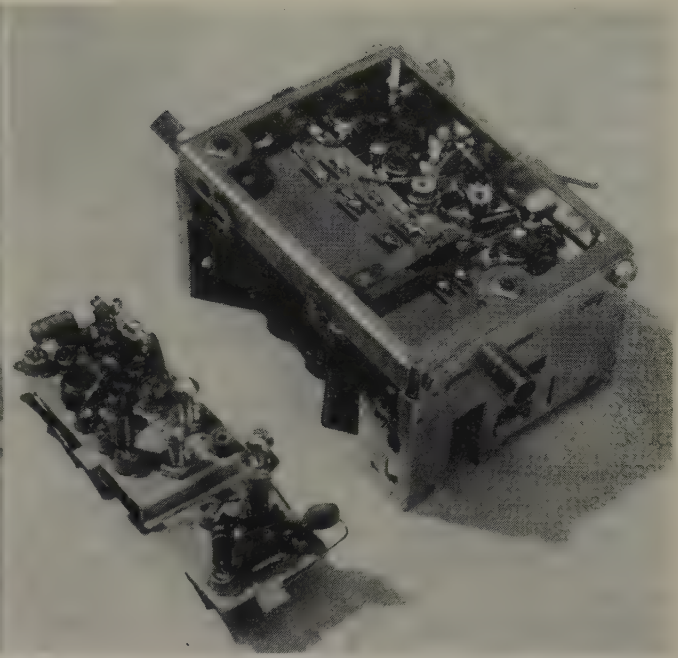

Fig. 14—Underside of the sub-assembly and the finished tuner.

Overall Performance & Field Tests

Fig. 15 contains a tabulation of typical overall performance from this transistor tuner. Note that high channel noise figures are about equivalent to those of pentodes. The low channel noise figures are better by 2 *db.;* however, the value of good low channel noise is modified by galactic noise. Rejections of the order shown here are excellent and this includes overall radiation rejection, which at its worst point is 2/1 below the F.C.C. limit of 150 $\mu V/m$ on the high channels and 50 $\mu V/m$ on the low channels.

Field tests of overload and cross modulation were made using the manually switched gain control system previously described. With this gain control system no particular overload problem was found with levels as high as .4 volt at 300 ohms input.

Cross modulation tests were based on the vacuum tube analysis which shows that percentage cross modulation is proportional to the square of the interfering voltage and independent of the desired voltage.

The test is carried out in the field by comparing the transistor tuner with a tube tuner in similar model receivers. The test consists of connecting a variable attenuator between the receiver and its antenna in the presence of strong signals until the desired picture is interference free. This is done at the same time for both transistor tuner receiver and tube tuner receiver. The difference between the required *db* attenuation for the two receivers is then an indication of their relative cross modulation capabilities. Using this method the transistor tuner was consistently within 4 *db* of a tetrode tube tuner for various desired signal levels even considering the broader input bandwidth of the transistor tuner.

Summary and Future Tuner Aspects

It has been the dual objective of this article to describe a particular *vhf* transistor tuner design and also to present some general design notes. It might be informative to sum-up the major differences in circuitry between the transistor tuner and the vacuum tube tuner, apart from stability and *d-c.* considerations. These are, most briefly then, for the *r-f* stage, the matter of *agc* and difference in behavior under gain reduction; for the mixer the necessity of a low input impedance at *i-f* frequency and low common side to ground impedance at *i-f;* and of course,

TRANSISTOR TUNER
V.H.F. MEASUREMENTS

CH. NO.	NF DB	GAIN DB	IMAGE REJECT DB	I.F. REJECT DB	FT RANGE MC	VSWR P	VSWR S	VSWR BEST	OSC RADIATION UV/M H
2	6.0	33.9	62	>70	3.0	2.8	1.8	1.8	* NL
3	6.5	31.7	70	>70					* NL
4	6.6	30.4	80	>70	3.5	3.0	3.0	2.8	* NL
5	7.0	28.4	80	>70					18
6	7.3	27.9	62	>70	4.0	2.3	2.4	1.9	35
7	10.2	20.0	63	>70	5.5	1.5	1.9	1.9	35
8	10.6	20.0	65	>70					70
9	10.8	19.3	69	>70					68
10	11.0	19.1	70	>70	5.0	1.9	2.4	1.9	77
11	10.8	18.7	70	>70					72
12	11.1	18.4	70	>70					49
13	11.4	18.1	70	>70	4.1	1.9	2.2	1.9	70

* NOISE LEVEL OF FIELD INTENSITY METER

Fig. 15—Overall Measurements.

overall, since the transistor is inherently a bi-lateral device, the isolation between stages should be given more attention for trouble free fast production.

As to the future, if it is believed that that which has been produced is then obsolete, this can surely be applied to the explosive semi-conductor field. Work on this particular tuner design was begun when the *madt* was the only transistor which could do the job at all. At this writing improved versions of both the *madt* and the *mesa* transistors have noise figures in the vicinity of 7-8 *db* at 200 *mc* which is a challenge to the best of conventional tube tuners, the cascode. Indeed there are hand-made advanced developmental samples of the *madt* which measures 4 *db*, surpassing the cascode. Much of the future will of course depend on transistor cost which is still relatively high, being approximately twice that for tubes. However, as the use of transistor tuners becomes more prevalent, it is natural to expect that cost adjustments should occur, leaving performance and size factors as ultimate criteria. It is felt to be something more than conjecture that the TV industry will reflect the momentum of high frequency transistor progress by a more extended use of transistor tuners in the near future, surely in the portable models and perhaps even in other lines.

Acknowledgment

The authors wish to express their sincere thanks to Vincent Friberg, Chief Engineer, General Instrument Corp. for his contributions to the design of the tuner, and to Leo Boltrucyk, Factory Engineer, F. W. Sickles Corp. Appreciation is also expressed to John Waring and K. Bearscove of the Philco Corporation Research Dept., and to C. D. Simmons of the Lansdale Tube Company, for their contributions to this article.

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Transistor AC Amplifier With High Input Impedance

JAMES J. DAVIDSON*

A circuit is described which has many useful properties for applications requiring an input impedance of a few megohms. It utilizes two transistors in a *d-c* closed-loop configuration having excellent temperature stability. The basic circuit operates to 65° C, while a variation, utilizing a Zener diode as the coupling element, is stable to over 100° C. The room temperature performance of both is identical. The circuit has unity voltage gain. The input impedance ranges from 1 to 4 megohms (depending on transistors) shunted by 40 to 60 mmf, when feeding a load of 2200 ohms. The resulting power gain is about 30 *db*, making the amplifier a useful coupling means from high impedance sources to subsequent transistor stages.

BECAUSE MOST OF THE ELECTRONIC ART has developed around the vacuum tube as the active element, many applications have arisen in which the input impedance of an amplifier *must* be high. When the transistor made its advent it had numerous advantages, but its relatively low impedance caused difficulty in such applications. Numerous approaches have been taken to circumvent or solve this problem, but no unique solution has been found for all areas.

The circuit described here has some advantages and some drawbacks when compared to the many others which have been proposed. Its major attributes are as follows:

Input resistance:	1-4 megohms, depending on transistor current gain.
Input capacity:	40-60 mmf.
Voltage gain:	Unity.
Power gain:	About 30 *db*.
Output impedance:	Less than 2 ohms (see text).
Frequency response:	Flat from a few *cps* to above 200 *kc*.
Temperature range:	—80°C to above 100°C.

The circuit consists of a two-stage amplifier with 100% negative feedback from output to input. The transistors are both of the same conductivity type (*n-p-n* or *p-n-p*), and the figures above are based on germanium units. With silicon, the temperature range could no doubt be considerably extended.

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The Basic Configuration

Most high input impedance circuits, in one way or another, include the emitter follower as a basic building block. Although the development of this particular circuit did not proceed with that idea in mind, it can be conceived of as a modified emitter follower, its distinction being that it has an "active" load.

The basic emitter follower configuration is well-known,[1,2] and the simplified circuit, ignoring bias, is shown in *Fig. 1*. The input impedance, to a first approximation, equals the current gain of the transistor times the load resistance. But since the major requirement of an emitter follower is often to feed a low impedance load, the circuit of *Fig. 1* is not sufficient to do the job. One of the more obvious methods to overcome this drawback is to cascade emitter followers, and numerous schemes for doing so have been proposed.[3,4] However, many of these circuits have complications of circuitry, and temperature stability problems.

The essence of the problem is to maintain a high load resistance in the emitter of the input transistor, regardless of the circuit loading. This means that something other than the first transistor must supply the major part of the load current, and this calls for at least one additional transistor. There are several ways in which the extra transistor (s) might be used (a second emitter follower is one way), but the method described here uses it as an "active" load.

Before proceeding to a description of the "active" load, consider first the circuit of *Fig. 2*. Here, transistor T_2 takes the place of R_L in *Fig. 1*. The circuit has the advantage of having an extremely high *a-c* impedance in the emitter of T_1, while allowing a relatively low *d-c* drop. This can be visualized from the idealized characteristic curves of *Fig. 3*. The *d-c* operating current of T_2 can be set to point Q_o (or anywhere else) by means of the battery in the base circuit. But the dynamic impedance is represented by the slope of the V_c-I_c curves, and can be extremely high. This scheme then allows the use of a high impedance load without the necessity of a concomitantly high-voltage power supply.

However, this circuit does not yet solve the problem of maintaining a high input impedance if the load hung on the output terminals is low. To do this, some way of "activating" T_2, and convincing it to supply load current is necessary. So let's examine exactly what would be required to accomplish the "activation."

The circuit of *Fig. 4* is simply *Fig. 2* redrawn, and with an external load added. For ease of visualization, imagine a positive-going pulse inserted into the input terminals. Since an emitter follower has no phase inversion, a positive pulse will likewise appear at the emitter of T_1, and consequently at the load. If, now, a positive pulse were also forthcoming from the *collector of* T_2, the emitter of T_1 would not be required to supply all the load current. But this could readily be done if a negative pulse were supplied to the base of T_2, as shown by the dotted pulses. And such a negative pulse is available if a load resistor is inserted in the collector of T_1.

Adding the load resistor and connecting the base of T_2 to the collector of T_1 completes the *a-c* circuit, as shown in *Fig. 5*. This configuration resembles that

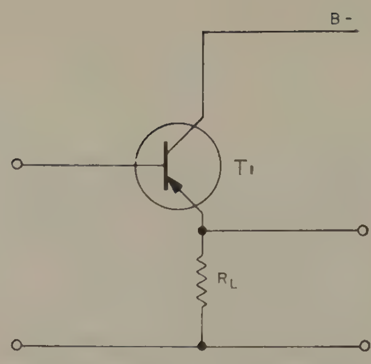

Fig. 1—Basic emitter follower.

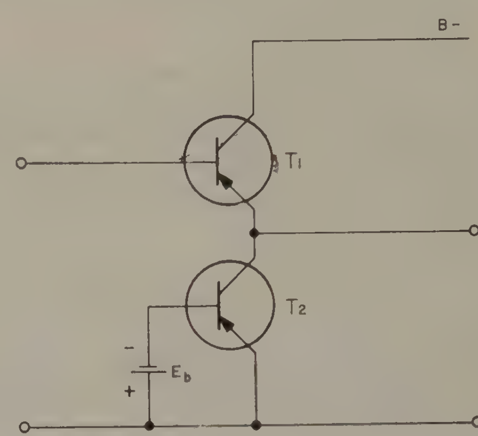

Fig. 2—Emitter follower with a transistor load.

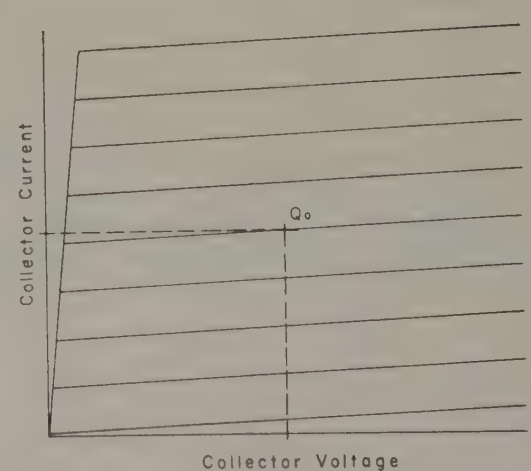

Fig. 3—Transistor characteristic curves (idealized).

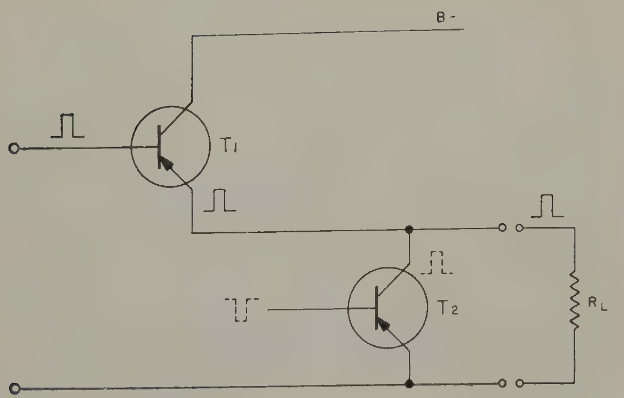

Fig. 4—"Activating the load".

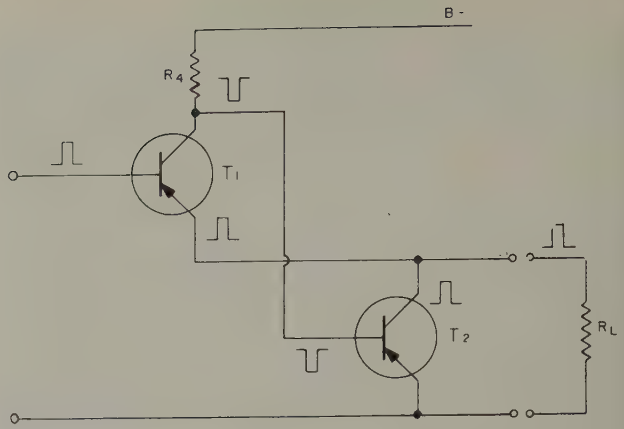

Fig. 5—Emitter follower with "activated" load.

described by Middlebrook and Mead.[5] Of course the circuit is not yet operable, since no allowance has been made for biasing requirements. This will be covered later, but first let's reexamine the circuit from a different viewpoint, which may prove useful for the purposes of calculation.

An Alternative View

As an alternative to the "activated" emitter follower, the circuit can be considered to be a two-stage amplifier with 100% feedback. The basic two-stage amplifier (ignoring bias) is shown in *Fig. 6*. If negative feedback is taken from the collector of T_2 to the emitter of T_1 (see *Fig. 7*), the input impedance will rise and the output impedance will drop. The amount of feedback is determined by R_{10}, R_9, and the impedance looking into the emitter of T_1. If R_9 is now made infinite and R_{10} is made zero, the circuit of *Fig. 8* is obtained. The only difference between this and *Fig. 5* is that the collector load of T_2 is finite. For reasons which will be covered later, this is often desirable. However, the basic operation is not altered by inserting R_7 into the circuit, and both circuits can be considered either as feedback amplifiers or "activated" emitter followers.

Biasing and Temperature Stabilization

For the purposes of discussing biasing and temperature stabilization, the circuit will be considered as a two-stage amplifier, since this approach yields the greatest insight. As a start, consider the feedback amplifier of *Fig. 9*. Each stage is separately biased; the first stage directly by a divider on the B supply, and the second by collector-to-base *d-c* feedback. The coupling capacitor, C_2, isolates the second stage from the first. Feedback is taken from the collector of T_2 to the emitter of T_1 through the network consisting of C_4 and R_{10}. If flat frequency response is desired, C_4 is made as large as possible, and serves only to block direct current. But with a little imagination it can be seen that given a reasonably high B supply, the collector of T_2 could be designed to be at the same potential as the emitter of T_1. If this is done C_4 becomes unnecessary, since there is no *d-c* voltage difference for it to block. It can then be removed without altering the circuit.

Unfortunately however, eliminating C_4 degrades the temperature stability of T_1. For example, if the bleeder of T_1 is heavy enough to hold the base voltage fixed, a rise in temperature will normally cause the collector voltages of both transistors to drop. But in addition, the drop in collector voltage of T_2 also

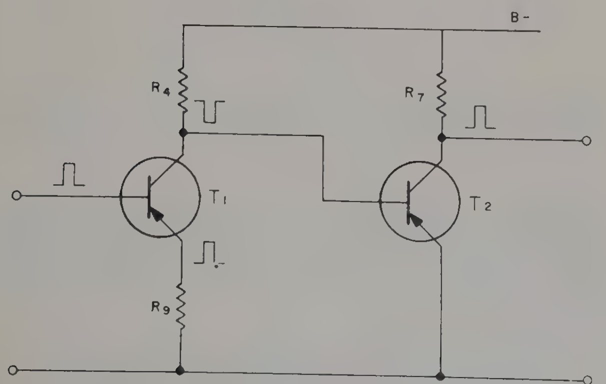

Fig. 6—Basic two stage amplifier.

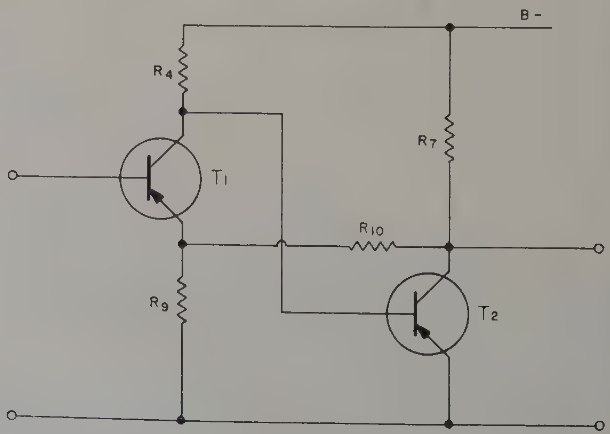

Fig. 7—Basic two stage amplifier with feedback.

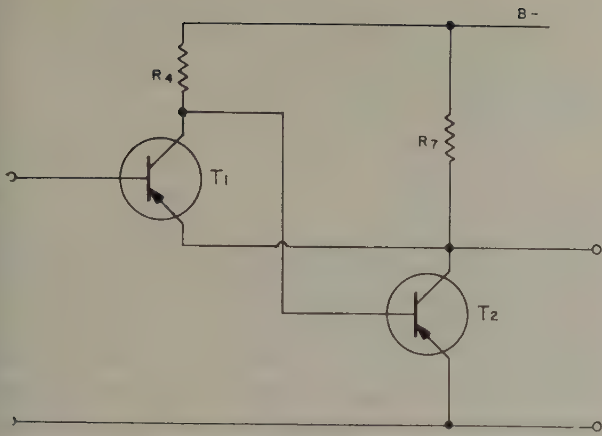

Fig. 8—Basic amplifier with 100% feedback.

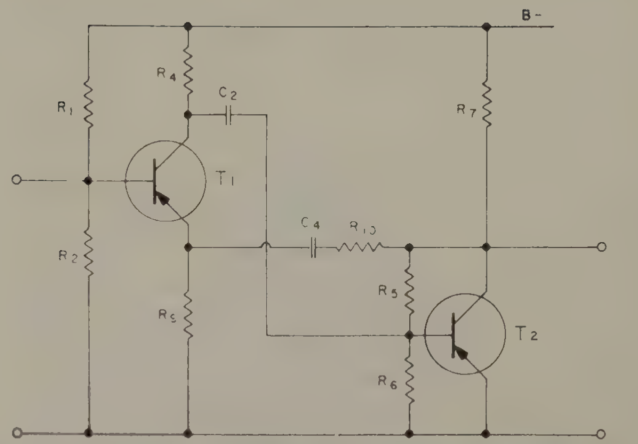

Fig. 9—Two stage feedback amplifier with bias and stabilization.

lowers the emitter voltage of T_1, causing T_1 to conduct even more heavily and lowering its collector voltage still further. In other words, the operating point of T_1 has been made dependent upon conditions with T_2, but in the wrong direction. This is clearly an undesirable state of affairs, and something must be done about it if operation at elevated temperatures is required.

The simplest way around the difficulty is to make the operating point of T_2 also dependent on conditions within T_1. This can readily be done by biasing T_2 from the collector of T_1, rather than from its own collector. There is now a continuous *d-c* loop encompassing both transistors, and the circuit looks like that of *Fig. 10*. *D-C* operation has now been made self-stabilizing in the following manner: If the temperature rises, the reduced collector voltage on T_1 supplies less bias to T_2, tending to cut it off and raising its collector voltage. This rise also raises the emitter voltage of T_1 (the base voltage is assumed fixed), tending to cut T_1 off and raising its collector voltage back up. The same reasoning applies to a reduction of collector voltage in T_2. The result is nothing more than closed loop *d-c* feedback, and the extent of the stabilization depends on the forward loop gain as well as the percentage feedback.

Simplifying the circuit still further, R_9 and R_{10} can be eliminated, increasing the feedback to 100%, and resulting in the circuit of *Fig. 11*. The amplifier now has unity voltage gain and is capable of supplying power to a reasonably low impedance load.

Bootstrapping the Input

There is one major drawback to the circuit of *Fig. 11*, however. Its input impedance is not particularly high. The input impedance is largely determined by the bleeder resistors R_1 and R_2, and since these must be moderately low for good temperature stability, much of the signal is shunted through them. Since the purpose of this amplifier is to provide a high input impedance, the situation is unsatisfactory. The problem is that the base of T_1 must be supplied from a bias source of direct current which has a moderately low impedance, but at the same time the *a-c* impedance seen by the base must be extremely high. A couple of possibilities—inductors or additional transistors—present themselves, but the actual solution is much simpler.

Consider the biasing scheme shown in *Fig. 12*. There is a generator in series with the bias resistor which is hypothesized as being capable of supplying a signal *identical* to the input signal. Without worrying about how this generator works, it is apparent that no signal

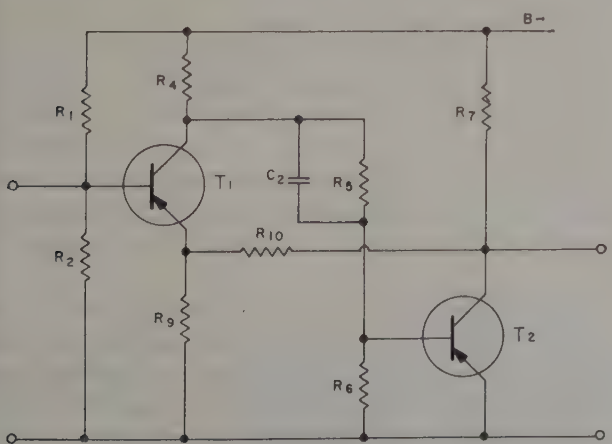

Fig. 10—Cross-coupled feedback amplifier.

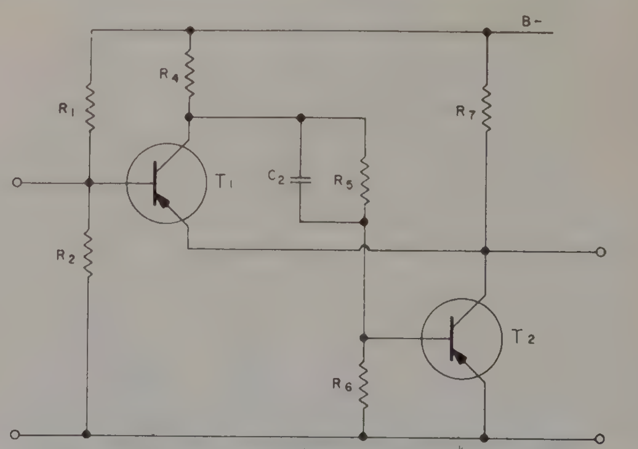

Fig. 11—Cross-coupled amplifier with 100% feedback.

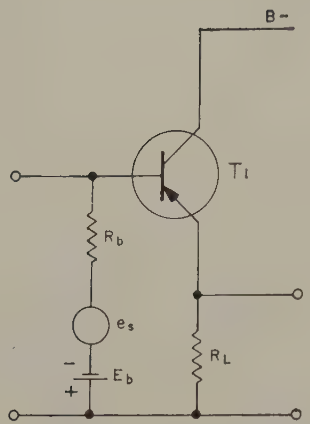

Fig. 12—Biasing for high input impedance.

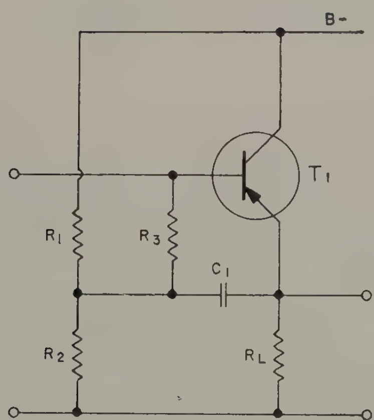

Fig. 13—Bootstrapped emitter follower with high input impedance.

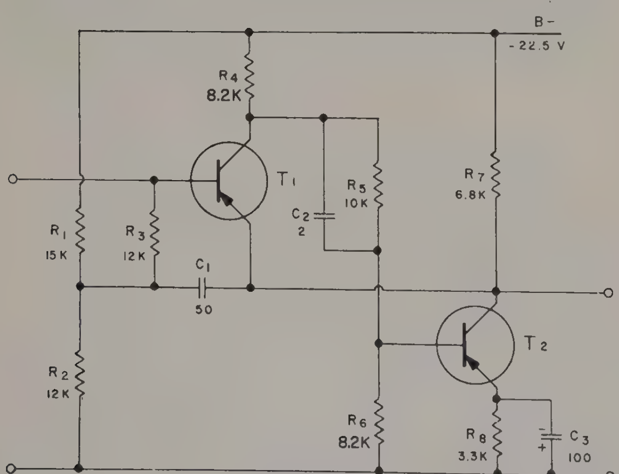

Fig. 14—Unity gain amplifier with high input impedance.

current will be drawn through R_b, since both ends of it are always at the same *a-c* potential. Therefore, so far as the signal is concerned, R_b is infinite. Yet it is still a reasonable impedance to direct current.

The essence of this idea can be incorporated into any emitter follower, as shown in *Fig. 13*. The bias battery E_b is replaced by the voltage divider R_1 and R_2. The signal bucking source is supplied through capacitor C_1 from the emitter, where almost an exact replica of the input signal is available. Assuming a reasonably high value of load resistance (voltage gain close to unity), the actual value of R_b can effectively be multiplied many times. Indeed, if the voltage gain could be made exactly unity, R_b would appear infinite when looking into the input terminals.

A note of caution concerning the bootstrap capacitor C_1: the voltage across it reverses as the temperature rises. Therefore an ordinary electrolytic is not usable in this function. Either a non-polarized capacitor or two electrolytics back-to-back are necessary. The voltage reversal occurs due to the voltage drop across R_3, caused by increasing base current as the temperature rises.

With the incorporation of the well-known bootstrap idea, a complete circuit results which maintains an input impedance of several megohms with good temperature stability. Its operation is described in the next section.

A Complete Circuit

Fig. 14 shows a complete and operable amplifier utilizing the principles already discussed. The circuit has been described in the Patent literature.[6] It performs well up to a temperature of about 65°C. The input resistance is in the range of 1 to 4 megohms, depending on the particular transistors used, and the frequency response is flat to several hundred kilocycles. The voltage gain, of course, is unity. The transistor operating points have been selected to fit a wide range of applications.

Choice of Operating Parameters

There are several factors to be considered in choosing the operating conditions of the transistors. For instance, since the circuit is quite likely to be used as the input of an amplifier, the first stage should be designed to ensure low noise. To this end, an operating current of 0.3 *ma*, and an emitter to collector voltage of 4 volts have been chosen.[7] While lower currents might result in lower noise at high source resistances,[8] the input impedance will suffer drastically from the reduced beta that goes with low emitter current.

The quiescent current in the second stage is dictated primarily by the load that must be fed. (For reasons which will be covered later, the collector-to-emitter voltage was chosen to be 3 volts.) If 2200 ohms is chosen as a representative load, then a 3 volt peak swing requires a peak current of 1.36 ma. As a

safety margin, the operating current was designed to be 2.0 ma, allowing for variations in circuit parameters. (For applications where it may be required, nearly a volt rms into 600 ohms can also be obtained with these operating parameters.)

Transistors to Use

In a circuit with as much feedback as this one (over 30 *db*), high-frequency phase shift can be a serious problem. To avoid the pile-up of phase shift while the forward gain is still high, transistors with very dissimilar cut-off frequencies should be used. The best choice is to use one high-frequency and one audio-frequency unit, and since low input capacity is a generally desirable attribute, the *r-f* unit should be in the first stage. With such a combination, the capacity runs 40 to 60 *mmf*.

As to specific transistor types, the 2N139 or any equivalent alloy junction *r-f* unit, can be used for the first stage. A 2N109 or equivalent high-beta audio unit is satisfactory for T_2.

If the amplifier is to be used where noise is an important parameter, the 2N139 should be checked for noise factor.[9] These transistors are not intended for audio use, so no effort is made to control audio noise during their manufacture. However, based on experience, the chances of finding quiet ones are good.

Input Resistance

The maximum input resistance of the amplifier is limited by a combination of three factors: the collector-to-base impedance of T_1; the small signal current gain (β) of the transistors; and the amount of available feedback. While the collector-to-base impedance of T_1 forms the ultimate limit for this circuit (since it is directly in shunt with the input), under normal conditions the other factors are of greater importance.

Figures 15 and 16 show the effect of differences in β on the input resistance.* As might be expected, increasing the gain increases the resistance, by a factor nearly proportional to the log of β. The high end flattening of the curves in *Fig. 15* reflects the previously mentioned limitation of collector-to-base impedance, but this factor normally appears only with unusually high-gain transistors. It is usually profitable, then, to choose the highest β units available.

Output Impedance

In conjunction with this amplifier the term "output impedance" must be carefully defined in order to have

* In gathering the data for these figures, the current gain of each transistor was measured under operating conditions corresponding to those in the circuit. That is, the β of T_1 was measured at 0.3 *ma*, and the β of T_2 was measured at 2.0 *ma*, for each transistor tested. Also, for all tests the amplifier worked into a 2200 ohm load.

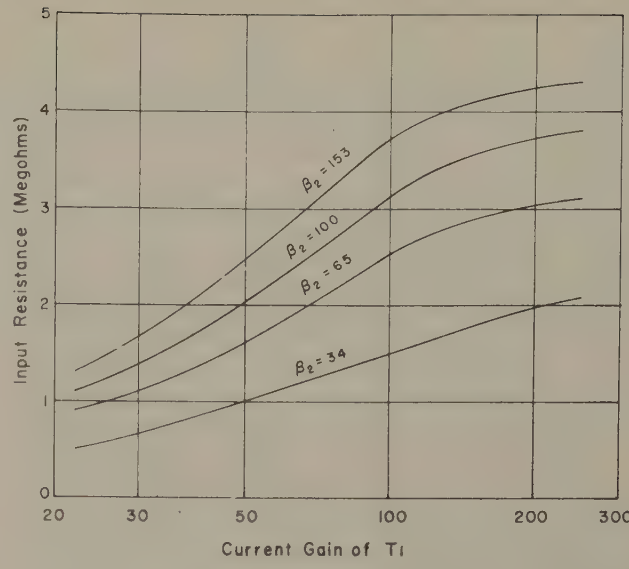

Fig. 15—Input resistance *vs.* Current gain of T_1.

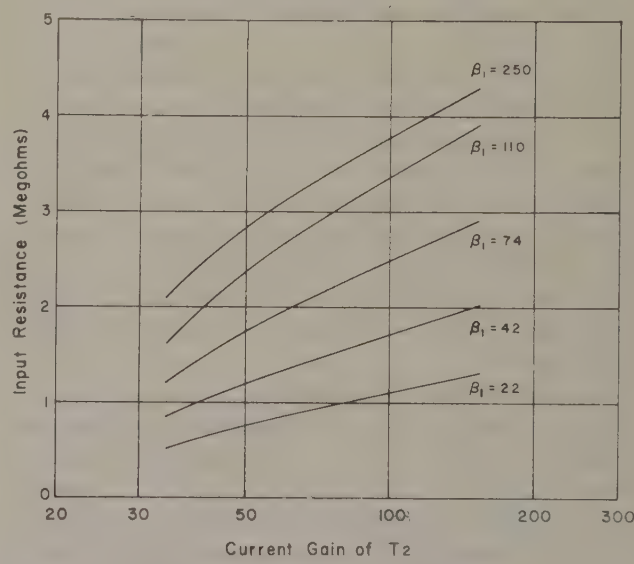

Fig. 16—Input resistance *vs.* Current gain of T_2.

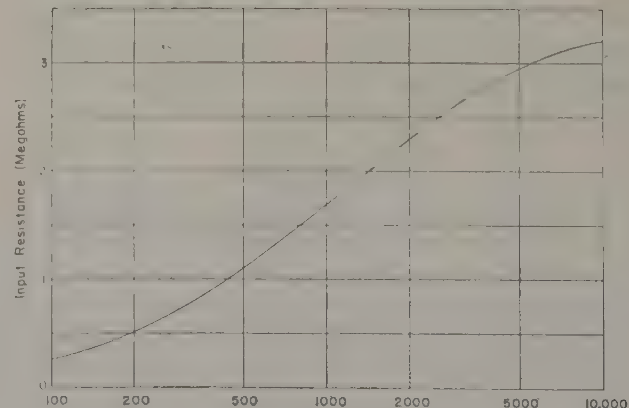

Fig. 17—Input resistance *vs.* Output load.

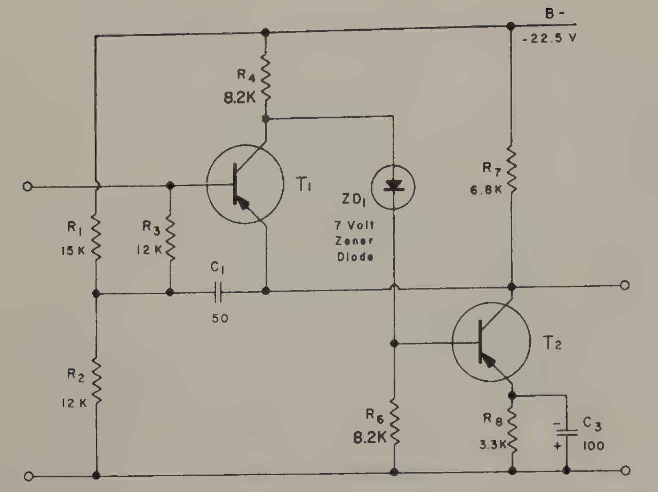

Fig. 18—High impedance amplifier with excellent temperature stability.

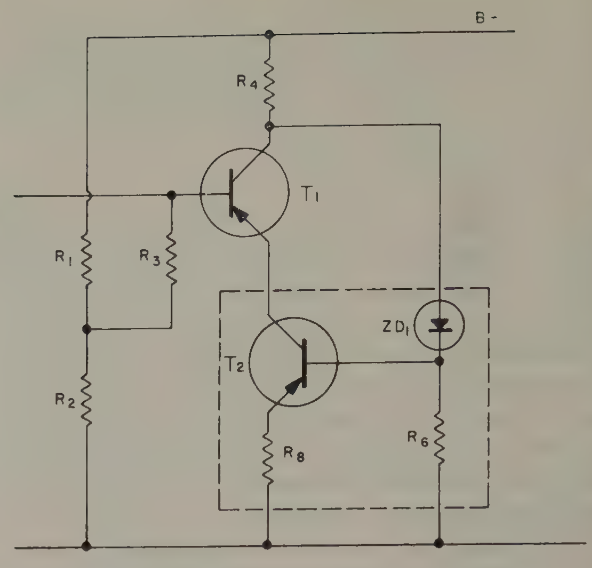

Fig. 19—Regulator action of T_2 on T_1.

any real meaning. Since both the input and output resistance are drastically altered by changing the percentage feedback, account must be taken of the effect on both when assigning numerical values. Even then the utility of the value assigned can be questioned, because of the specialized conditions under which it was obtained. With these reservations in mind, the output impedance was measured by the "half-voltage" method and found to be under 2 ohms. But loading the output with a 2 ohm resistor reduces the input impedance to 10,000 ohms and limits the maximum output to 3 millivolts, making the exact figure rather meaningless.

Of more interest and value is knowledge of how the input impedance varies with output loading. This relationship is shown in *Fig. 17* for a range of load resistors from 100 to 10,000 ohms. At both the upper and lower extremities the input impedance approaches asymptotic values. The lower asymptote is formed by the input impedance of T_1 without feedback (a few thousand ohms), and the upper asymptote reflects the fact that R_1, R_2, and R_7 (a total of 3.3K) are already shunted across the output, setting a maximum to the available feedback. The upper limit could be raised by the simple expedient of increasing the supply voltage, enabling all the resistors to be increased, but if the load is to be a transistor or other low impedance the improvement will be marginal.

The Final Circuit

Although the circuit of *Fig. 14* is satisfactory for many (if not most) applications, there are often requirements for amplifiers that will work above 65°C. In order to push the operation of this circuit to beyond 65°, additional stabilization is necessary. To see how this can be accomplished, let us analyze the limitations of the circuit of *Fig. 14*. Considering T_1 first, two effects of increasing temperature are apparent; saturation current flowing into the base will cause the base voltage to rise from its original value; and excess collector current (due to increased base current) will cause the collector voltage to drop. In the second transistor, identical effects are present. Now the presence of the *d-c* feedback loop will tend to offset these changes, as outlined previously, but the amount of compensation is directly dependent on the *d-c* loop gain.

As is evident from *Fig. 14*, there is one point at which the *d-c* gain is being needlessly reduced; in the divider (R_5 and R_6) from first collector to second base. The only purpose of R_5 is to maintain a voltage difference between these points. A battery would serve as well. (Better, actually, since no bypass capacitor would be required.) And a battery would enable any change in V_{c1} to be coupled directly to the base of T_2 without attenuation or division. But floating batteries are unpopular devices. Fortunately, there is another type of device which performs the required function admirably, the Zener diode.

Substituting a Zener diode for R_5 and C_2 results in the circuit of *Fig. 18*. The choice of a voltage rating for the diode is dictated by the operating conditions of the transistors, being the sum of the voltages across both units. The voltage across T_1 has already been specified as 4 volts for noise reasons, and the voltage across T_2 can be somewhat arbitrarily designated as 3 volts. A 7-volt diode is then required. (As the astute reader will no doubt deduce, a 7-volt diode was available, and the transistor voltages were tailored to fit. But it worked out beautifully.)

This simple substitution of a Zener diode results in some unusual properties, since the circuit is now operable to over 100°C, although its performance at room temperature is identical to that of *Fig. 14*.

The implications of this approach are significant enough to make it worthwhile to analyze the circuit in detail.

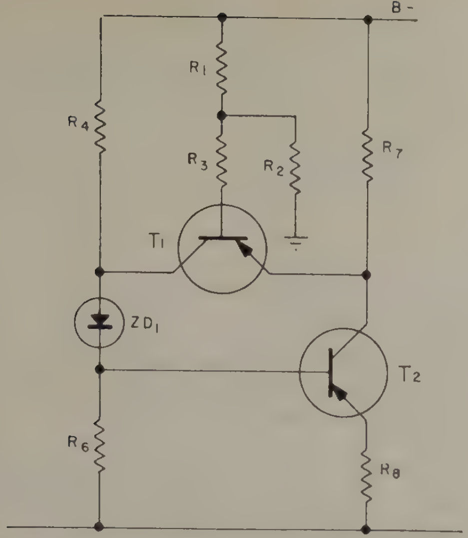

Fig. 20—Regulator action of T_1 on T_2.

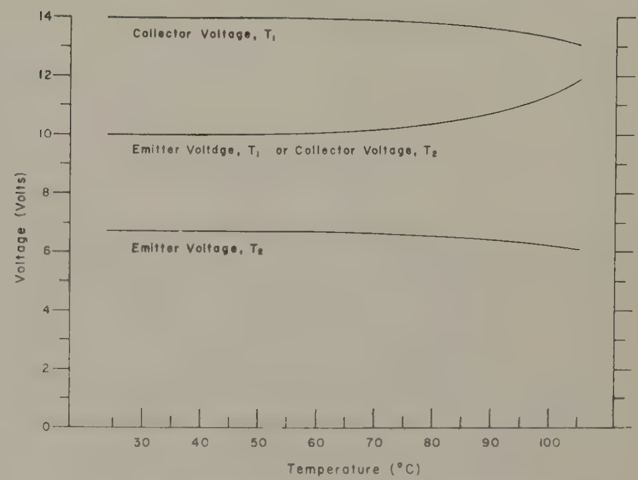

Fig. 21—Voltage variation *vs.* Temperature.

Temperature Performance

The circuit of *Fig. 18* has the unusual property that each transistor can be looked upon as an "operating point regulator" for the other transistor. To start, consider T_1 as the transistor whose operating point is to be regulated. Simplifying, and considering only the *d-c* circuit, the circuit of *Fig. 19* can be drawn. The elements within the dotted box can be considered as the regulator, and it operates in the following way. Any change in V_{c1} is directly coupled to the base of T_2 via the Zener diode. The change is amplified, inverted, and applied to the emitter of T_1 in such a way as to offset the original change. Since the Zener diode insists on maintaining a fixed voltage between the collector of T_1 and the base of T_2, and since the base of T_1 is relatively fixed, the operating point of T_1 stays remarkably stable. The only limitation is the change in V_{b1}.*

Turning the circuit around, consider now that T_2 is to have *its* operating point regulated. See *Fig. 20*. Any change in collector voltage is applied to the emitter of T_1, amplified, and appears as a change in the collector current of T_1. But the only way I_{c1} can change (let's say increase), is to rob base current from T_2, which pushes the operating point of T_2 right back to where it was. And this stabilization is highly effective for the following reason. If the base voltage of T_1 can be assumed to be fixed, then the collector voltage of T_2 can't vary by more than 0.1 volt. This happens because a small change in the base-emitter voltage of T_1 (much less than 0.1 volt) causes a large change in its collector current. This in turn alters the bias on T_2 sufficiently to restore the original conditions. For all practical purposes, then, the collector voltage of T_2 is dependent only on the base voltage of T_1.

As can be noted, the major assumption throughout this discussion has been that the base voltage of T_1 remains fixed. But this is not true, and with the circuit of *Fig. 18* it is this variation which is the major limitation on high temperature performance. At something over 100°C the base voltage rises to meet the collector voltage, and T_1 goes into saturation as shown in *Fig. 21*. It can be seen that the collector voltage of T_1 drops only slightly at 105°C, paralleling exactly the drop in emitter voltage of T_2. (The Zener diode insures that action.) But the emitter voltage of T_1, following its base voltage, rises fairly sharply, tending to throw the transistor into saturation. While various compensating schemes for overcoming this drawback can be devised, germanium transistors suffer enough in other ways above 100° (loss of small-signal current gain and poor life), that the improvement would be doubtful value. For operation at temperatures beyond 100°, silicon is the best bet.

The only remaining temperature limitation of the circuit of *Fig. 18*—the base current drawn by T_2—can readily be sidestepped. Because the bias on T_2 is determined by the voltage across R_6 (which in turn is caused by a combination of the current through the Zener diode and the base current), if the bleeder current is made large enough the base voltage will remain essentially fixed to the highest temperature of interest. But the current can't be made too high, because then R_4 would have to be too low, reducing the forward *d-c* loop gain. Therefore the current is made as high as necessary, but no higher. A value of 0.85 *ma* was selected.

Just why this particular value was chosen can be seen from *Fig. 22*. At 105°C, it has been reduced almost to zero. The cause of this phenomenon is as follows. At low temperatures the base of T_2 draws almost no current. Therefore whatever voltage appears across

* This type of stabilization may also be useful in conditions where single-stage amplifiers *must* operate at extremely high temperatures—and cost is no object. In *Fig. 18*, if C_1 and C_3 are removed, R_3 shorted out, and a bypass capacitor placed from the emitter of T_1 to ground, a single-stage amplifier operable to over 110°C is obtained. The output would be taken from the collector of T_1, and the circuit will act like any common-emitter amplifier except for its unusual temperature range.

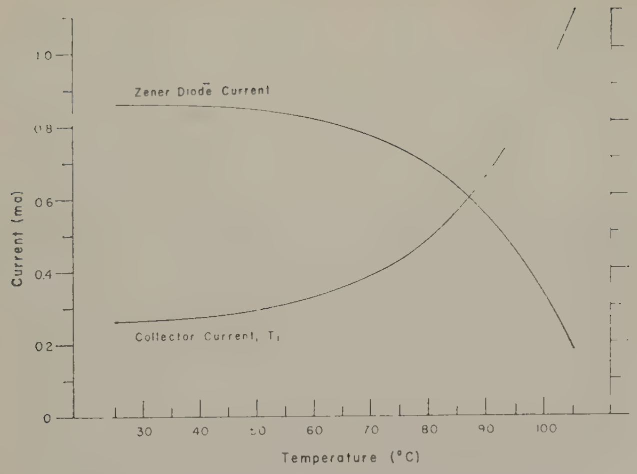

Fig. 22—Current variation *vs.* Temperature.

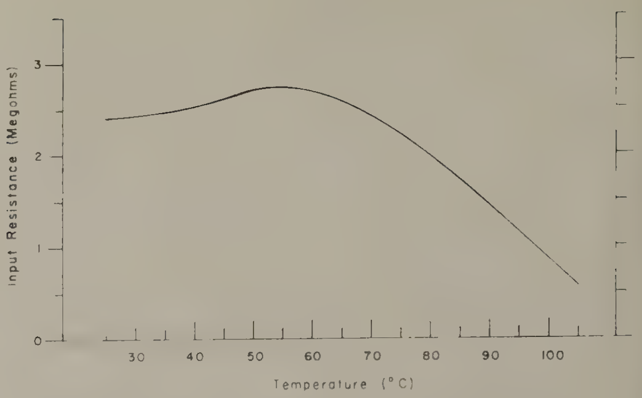

Fig. 23—Input resistance *vs.* Temperature.

R_6 is a result of current flowing through the diode. As the temperature rises, and base current begins to flow, T_2 tends to conduct more heavily. But this drops the collector voltage, in turn dropping the emitter voltage of T_1 and causing it to conduct more heavily. This, in turn, robs some of the current from the diode and sends it through T_1 instead. The compensation is such as to nearly perfectly offset the increase in base current of T_2 by a reduction in the current through the Zener diode, maintaining the base voltage constant.

Of course, the robbed current must go somewhere, and the sharp increase in the collector current of T_1 in *Fig. 22* is where it went. While this increase may be a drawback in some applications, it seems a small price to pay for the magnitude of stability which has been achieved.

Input Impedance and Temperature

The one remaining item of interest is the variation of input resistance with temperature. *Fig. 23* shows this under the following conditions: Current gains of T_1 and T_2, 61 and 93, respectively; load resistor, 2200 ohms; frequency, 400 *cps.* The transistors were deliberately chosen to represent nominal units, so the curve indicates what should be normal performance. The 15% rise in impedance at 50°C is presumed to be a combination of the normal slight rise of beta with temperature, and the slightly increasing collector current of T_1 (as shown in *Fig. 22*) causing an increase in beta.

Beyond this point the steadily dropping resistance reflects the loss in gain of germanium transistors at elevated temperatures.

Conclusion

A circuit has been described which should find a wide range of use in applications where a moderately high input impedance is required, such as the direct replacement of vacuum tubes in audio circuits. In addition, a new approach to temperature stabilization was outlined which may find use in special situations requiring operation at extremely elevated temperatures.

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Solid State Power Inversion Techniques

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Part 1

Some fifteen years ago Dr. E. F. W. Alexanderson made the following observation in an A.I.E.E. transactions paper,(1) "The term 'electronic power converter' needs some definition. The object may be to convert power from one frequency into another, or to serve as a commutator for operating an *a-c* motor at a very low speed, or for transforming high voltage *d-c* into low voltage *d-c*". This is even more true today, for the terms inversion and conversion are often used very inconsistently and often not very accurately. When electronic apparatus (non-rotating equipment) is used to convert *a-c* power to *d-c* power it is called a rectifier. The same apparatus can be used to reconvert *d-c* power to *a-c* power by means of simple adjustments of its control. When so operated, it is called an inverter. Notice the slightly different meaning that is often associated with the term, for in strictly electronic parlance an inverter produces an "up" output for a "down" input, or a "one" signal for a "zero" input signal.

The portion of the system in which the *d-c* power flows is called the *d-c* link. The combination has been termed a converter. The *d-c* link may be lengthened until ultimately it might be termed a *d-c* power transmission system. Likewise, such a system may be termed a frequency changer if *d-c* transmission is not the primary objective. In addition, clarification is necessary as to the method of inversion and methods of commutation. It is the specific purpose of this article to serve first in a review capacity and secondly in a clarification capacity by means of certain suggested terminology.

In the 1930's a new electrical industry was foreseen where power would be transmitted long distances by high voltage *d-c*, railroads would be electrified by locomotives carrying electronic converters from a high voltage *d-c* trolley to low voltage *d-c* motors, etc. Thirty years later this indication appears to be becoming a reality with many lower power ratings, particularly in the military, spearheading the growth. There have been a few power applications involving ratings up to 20,000 kw. Some systems, such as the installation at the Carnegie-Illinois Steel Corporation,[2] involve the interconnection of dissimilar power systems. In this case, involving two 10,000 kw equipments, a 60 cycle and a 25 cycle system are connected so that they either rectify or invert depending on the system requirements. A number of systems are used in connection with motor loads in order to improve the overall system performance. One such system being designed uses a 10,000 *hp* *d-c* motor operating from a high voltage *a-c* supply.

All inverters are characterized by ease of frequency control and frequency accuracy as compared with rotating machines. Accuracy of the order of 1% is easily achieved with tuned circuits, while 0.1% usually requires the use of a tuning fork and greater accuracy the use of a crystal. Values of 0.001% are not difficult to achieve. On the other hand voltage control and overload characteristics are sometimes more difficult. Recent circuit work is fast removing these problems with static inverters. In addition to the obvious uses for high accuracy power sources, inverters offer quieter operation and instant starting such that within a half cycle the output is normal.

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General Requirements

There is presently a rebirth of interest in the subject of inversion which is a result of the availability of semiconductor devices and superior magnetic materials. In most cases this has been caused by the military as a result of the need for more reliable, high efficiency, lighter, smaller, and quieter power inverting equipments. Of immediate concern is the field of *d-c* power sources including fuel cells, solar batteries, thermoelectric, and thermionic converters, in addition to the superior energy storage capacities of modern batteries. A limitless field of commercial and industrial applications is being explored and will follow in the next few years. Primarily, the attraction of many of these elements is in their static operation with comparatively low dissipation and high reliability. The switching element is the heart of the inverter. It is a power device gating the flow of electrical power from input to the output side of the inverter. The internal dissipation, like that of a transformer, should be a small fraction of the power it transmits. The ratio of the power dissipation in this element to the power transmitted to the load is a measure of its effectiveness. The switching element is a non-linear component, including such devices as transistors, thyratrons, controlled rectifiers, vibrators, flip-flops, etc. Necessarily, the controlling device must be a series element which gates the current flow rather than a shunt device if any degree of efficiency is to result.

Recently, an attempt was made to determine the ideal characteristic required for the series gating de-

vice of an inverter. This analysis was basically an outgrowth of an attempt to see whether or not magnetic components or similar passive devices could perform the function of inversion. It was concluded that the use of reactive elements only is out of the question, since a net average forward current and a net average forward voltage give a product that is positive and finite, whereas, for a reactive element, the product of the average values of current and voltage must be zero. This same statement is true for capacitors, as well. An inductance may conduct a continuous net average current but will not hold off that average voltage for a cyclic period. Hence, the product of its average current and voltage is zero. The same conclusion applies for a transformer or saturable reactor as for a linear reactor. One must conclude that a reactive component alone can be used neither as a rectifier nor as a bistable switching element. Combining reactive elements will in no manner relieve these restrictions. However, reactors do perform a valuable service function for controlling the inverter output or feedback when they are so utilized.

Historically, several electromechanical devices such as dynamotors and vibrators (mechanical and mercury) in conjunction with transformers have been useful in changing *d-c* to *a-c*. A basic circuit for a vibrator approach is shown in *Fig. 1A*. These equipments are restricted to relatively low power levels up to a few hundred watts, and of course have weight, size, noise, life and "hash" problems. It is also proposed that eventually the cost of the semiconductor approaches will actually be less expensive than the methods based on the relatively fixed (if not rising) cost of iron and copper as contrasted to the sharply declining cost of silicon and germanium. Indeed in cases where isolation and/or impedance transformation is required operation of the magnetic devices at higher than normal commercial frequencies in conjunction with semiconductors may be more economical than merely the magnetic approach alone. It is also possible to change *d-c* to *a-c* solely by the use of rectifiers, as shown in *Fig. 1B*. However, this approach requires the presence of an *a-c* voltage and is usually utilized in low power, signal type applications.

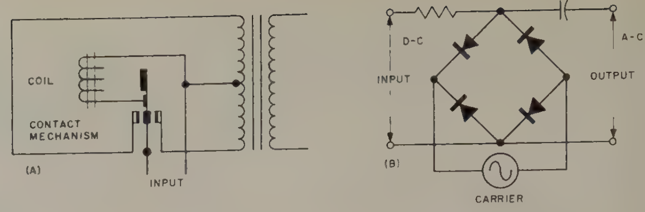

Fig. 1A—Vibrator transformer inverter circuit. Fig. 1B—Diode modulator circuit.

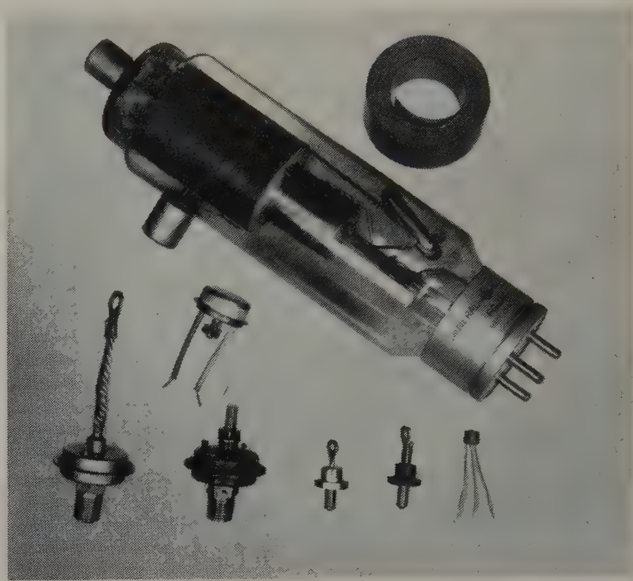

Fig. 2—(Top) Thyratron, tape wound toroidal core; (Middle) 13 ampere germanium transistor; (Bottom) Silicon high current rectifier, 50 ampere; Silicon controlled rectifier, medium current; Silicon; rectifier; 15 ampere silicon controlled rectifier (C35); Silicon unijunction transistor.

Solid State Device Characteristics

Fig. 2 shows a picture of a number of solid state components which have been influential in causing the rebirth of interest in inversion. Silicon and germanium rectifiers have offered new concepts of efficiency, particularly for low voltage supplies and operating temperature possibilities. Square loop core materials having nearly rectangular *"B-H"* hysteresis loops, as shown in *Fig. 3C* offer extremely effective saturating component design.

Further the abrupt wavefronts produced are extremely rapid, approaching the fastest semiconductors in properly designed units. The preservation of high working flux densities and availability of tape thicknesses from one-eighth mil up allow designing for high power levels and efficient operation at high frequency.

The unijunction transistor is an important device for use in inversion, ranging from timing and driving applications to feedback circuits.[3] This device uses one bar of silicon with a tap (emitter connection) at the inner base region. The device possesses switching action between this emitter and the base "1" connection, as shown in *Fig. 3B*. This switching action is very precise from a voltage and temperature viewpoint, which together with an extremely rugged mechanical design makes for a very reliable control device.

It will be beyond the scope of this article to consider all of the types of semiconductors available, so that only the more important will be considered. Normal junction transistors are proportional control devices. Generally, when used in connection with power circuits the switching mode of operation is utilized as shown in *Fig. 3D*. Notice that the device requires continuous base drive to hold the switch in the closed or conducting position "C." Commercial transistors, primarily germanium, have been designed for handling reasonable currents at peak voltages approaching 100 volts. A unit rated for 13 amperes is shown in *Fig. 2*. While the frequency response of transistors is not sat-

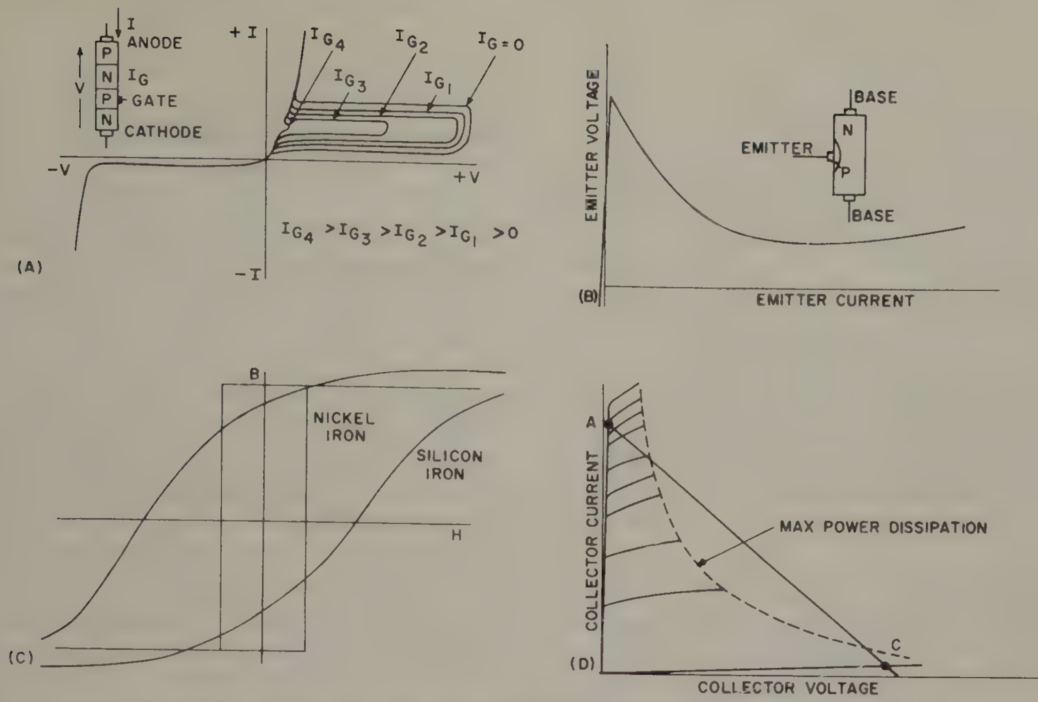

Fig. 3—(A) Silicon controlled rectifier characteristics. (B) Unijunction transistor characteristic. (C) Hysteresis loops. (D) Transistor characteristics.

isfactory for some communication applications it is adequate for most inversion requirements. While considering transistors, it should be mentioned that "thyratron" transistors and point contact transistors have been available from time to time, offering bistable or switching properties. However, as a result of the superior junction designs from the standpoint of cost, reproducability, and stability such devices are virtually extinct.

The concept of the multijunction semiconductor has been receiving considerable attention lately. The *p-n-p-n* structure is perhaps the oldest of these.[4, 5] These devices offer outstanding characteristics for switching applications because of their near perfect characteristics, stability, high gain and potentially low manufacturing cost. Both two and three terminal devices are commercially available with multi-terminal units receiving much development attention.

The commercially available silicon controlled rectifier[6, 7] is one of the most important varieties. The production C35 unit rated at 16 amperes and a development model higher current controlled rectifier are shown in *Fig. 2*. Notice the similarity between the controlled and uncontrolled rectifiers. The commercial availability of the silicon controlled rectifier makes available for the first time a practical solid state device analogous to the familiar thyratrons. The use of this component circumvents some of the problems normally associated with transistor circuits such as restricted voltages, power, and current ratings and allows utilization of many of the important thyratron circuit concepts previously mentioned. The ability to operate at higher switching rates allows the use of new inverter concepts, to reduce the problems associated with starting, load changes, etc., in addition to reducing the size of filter and energy storage circuit components.

While the concept of a solid state switching device is not new, the availability of reproducible high power units is an innovation. From an application viewpoint, the approximately equal forward and reverse voltage rating is of considerable importance. The controlled rectifier is a silicon device utilizing some of the properties of transistors and rectifiers. Of significance is the fact that the unit is capable of being produced in large volume at an economical price figure.

The basic anode-cathode characteristic is considered in *Fig. 3A*. The controlled rectifier has a minimum power gain in excess of 150,000. On the basis of pulsed input, the power gain is much greater. The device has a deionization time which is considerably shorter than that occurring in thyratrons under most operating conditions. When conducting, the forward voltage drop is about 20% greater than for the equivalent silicon rectifier and drastically lower than the 12 to 15 volt drop in thyratrons. Peak voltage ratings in excess of 300 volts are presently available with higher voltage designs paralleling advancements in normal rectified P.I.V. ratings and packaging techniques. The allowable current depends on the junction area, method and effectiveness of cooling and current waveform. Water cooling offers a medium for considerably extending the allowable current per junction as with any rectifier. Available I^2t data indicates that proper fusing can be selected. Parallel, series and multiphase connections offer considerable flexibility in the appli-

cation area. As many as eight units have been operated in parallel without difficulty. At present the gate is used only to control the turn-on direction. The concept of turn-off by means of the gate is receiving attention and improvement in performance in this direction should result.

Not only is the controlled rectifier useful in the inverter itself, but, in addition, will be used extensively as a static switch in power and control circuits, in place of more conventional relays and other forms of switching amplifiers. Since the *C35* is basically manufactured in a manner very similar to the normal silicon rectifier, it should possess comparable life expectancy. Life data to date indicates no appreciable parameter changes when operating at maximum stud temperature. The use of silicon affords the optimum in terms of life expectancy, eliminating early unit failure due to impurities and process control.

Thyratron Techniques

Thyratrons, ignitrons, and silicon controlled rectifiers control the instant at which conduction takes place but thereafter the grid or gate loses control. Notice that the term "controlled rectifier" can apply to tubes as well as to silicon devices. Current in individual devices must be interrupted through the use of the external circuit which causes the current in the device to decrease to zero. After the current zero, the device regains its blocking characteristic and is thus pendent on its recovery characteristic and is thus ready to be refired at the proper time. Device recovery or deionization time governs the maximum operating frequency. The basic mechanism for reducing the current is called commutation. In any case, reactive loads will require a certain amount of added *kva* for proper operation. There are at least five ways in which thyratron type circuits may be made to commutate with either static loads or counter *emf* loads. These may be conveniently named according to the methods used as follows:

1. Phase commutation (Rotating machine commutation at fundamental frequency).
2. Parallel capacitor communication. (Capacitor in parallel with the load.)
3. Series capacitor commutation.
4. Harmonic commutation (Sometimes called interphase commutation).
5. Frequency commutation (As for example in frequency dividing circuits).

For inverting into *a-c* systems containing alternators phase and harmonic commutation are normally used, whereas parallel and series commutation are used for static loads.

The solid state thyratron in its application to inverters has posed problems reminiscent of those arising in thyratron equipments in the past. Tubes were subject to momentary random faults, "arc back" and "shoot through" (loss of control) etc. The first two should not be problems with solid state units. There are several causes of "shoot through" including voltage transients which trigger the device at the wrong time and failure of the device to fire such as in the case of the ignitron.

Fig. 4B shows a simple rectifier circuit using the *a-c* source and a pair of phase controlled rectifiers. The corresponding range of operation is from 0 to 90 degrees in *Fig. 4A,* while for greater angles (90 to 180 degrees) inversion takes place. Inverting into an *a-c* system is a common application of phase commutation and phase commutation accounts for more inversion *kva* than other methods of commutation. The heavy curve in *Fig. 4A* is the ratio of *d-c* to *a-c* voltage. Notice that for inversion in the range of 90 degrees, the *a-c* voltage will reach very large values for fixed *d-c* values theoretically approaching infinity). As the commutation angle approaches 90 degrees, the voltage sensitivity to load changes becomes worse since the ratio changes more for a given increment in commutation angle. The thin line indicates the amount of reactive *kva* flowing through the load. Notice that when the power approaches zero the reactive *kva* is approaching a maximum. Operation in the range from 180 to 360 degrees is only possible for forced methods of commutation, such as harmonic commutation or transistor type commutation where the device can open as well as close the circuit. Phase commutation is restricted to the 0 to 180 degree region.

Phase commutation[8] as applied to an inverter may be explained by referring to *Fig. 5.* Here it is seen that at the time t_1, the instantaneous voltage e_1 of phase A is greater than e_2 which is the instantaneous voltage of phase B. Therefore a current entering an inverter against the counter *emf* e_1 of phase A will be transferred to phase B by the instantaneous difference in voltage between phases A and B. However this transfer will take place in the proper direction only on the rising or leading side of the voltage wave. Therefore phase commutation as applied to an inverter is operative only when the current wave leads the voltage wave. That is, the load supplied by the inverter must have a leading characteristic.

Phase commutation is analogous to commutation by brush shifting in direct-current machines. Commutation is improved if the brushes are shifted in the direction of rotation (lagging) in a continuous-current generator (rectifier). The opposite brush shift (leading) improves commutation in a continuous-current motor (inverter).

There are two serious limitations of phase commutation as applied to an inverter:

1. An inverter employing phase commutation can supply only a load of leading-current characteristics.
2. Phase commutation in an inverter corresponds to a condition of unstable equilibrium. Any delay in the commutation of current, or any abnormal increase in the current, results in an insufficient commutating voltage and a failure to commutate. Phase commutation as applied to a rectifier has the opposite characteristic because any delay in

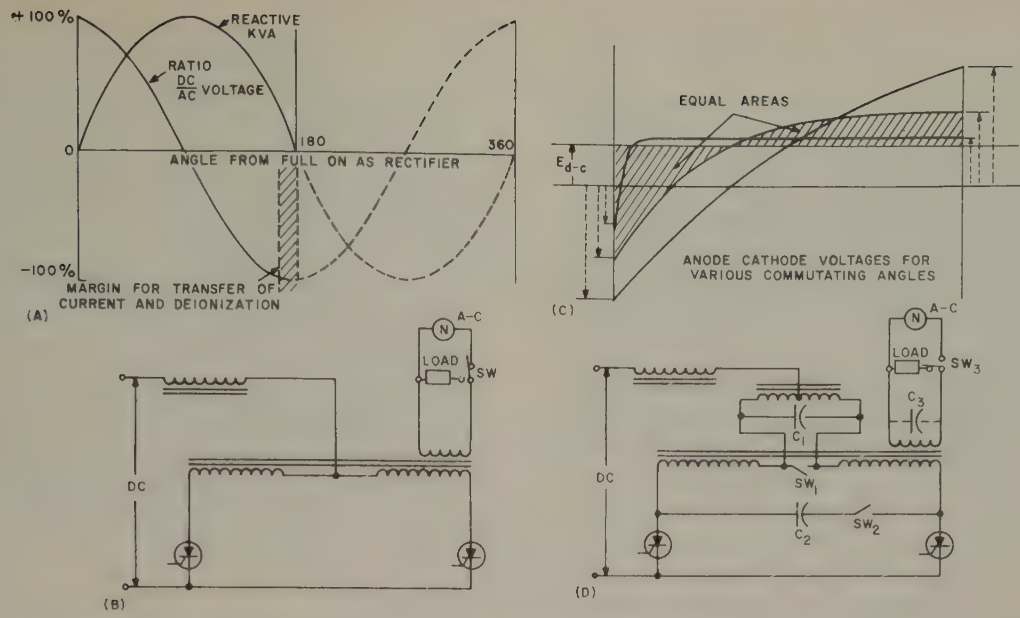

Fig. 4—(A) Reactive *kva* and voltage ratio as a function of angle. (B) Phase controlled rectifier circuit. (C) Anode-cathode voltage for various commutating angles. (D) Parallel inverter-series inverter circuit.

commutation or abnormal rise in the current results in an increased commutating voltage and therefore in a stable condition.

With phase commutation all common power rectifier circuits can be used for inversion.

An example of a phase commutator circuit is shown in *Fig. 7B*. A number of installations of this type have been made, involving *d-c* transmission, coupling of dissimilar power systems together, etc., as indicated in the bibliography.

The parallel inverter shown in *Fig. 4D* is perhaps the most common thyratron inverter circuit. Parallel capacitor commutation is provided by C_2 with SW_2 closed and SW_1 closed. Capacitor C_3 on the secondary of the output transformer can be used instead of C_2 to provide parallel commutation, but at a different impedance level, depending on the turns ratio of the transformer. The transfer of current will be somewhat longer because of the leakage reactance of the transformer, although some slowing up of the discharge of C_2 may also be desirable. The transfer of current must be considered as well as the ionization time to insure sufficient margin of commutation angle as shown in *Fig. 4A*.

Referring to the parallel case of "4D," it will be noticed that a series inductance is used to provide continuous current during commutation. The amount of inductance is somewhat of a compromise. It should be small to aid starting, but large enough to reduce current spikes during commutation. With a fixed resistor load an increase in commutation angle will result for increases in the commutation capacitance. In the case of non-resistive loads, the capacitor must match the power factor of the load while any excess amount will result in a larger commutating angle. Excess amounts of commutating capacitance mean a larger commutating angle and an increase in the *a-c* voltage, causing it to rise and vary widely with load. Saturation of magnetic components also becomes a problem. The control for the firing of the thyratrons is not shown. It may be derived from an external source or self-excited. This is also true of the other circuits shown in *Fig. 4D* with SW_2 is open and SW_1 open, the circuit functions by series capacitor commutation[9] furnished by C_1. *Fig. 6C* shows a series capacitor commutated inverter under one mode of operation but by insertion of the dotted capacitor becomes parallel capacitor commutated with a stiff capacitor divider. It is clearly evident that the method of commutation must be clearly stated in order to

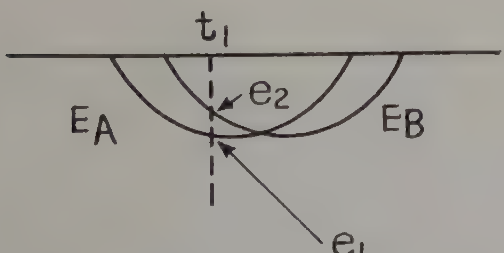

Fig. 5—Phase commutation.

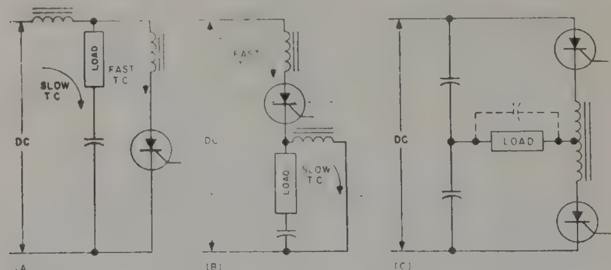

Fig. 6—Series inverter circuits.

avoid confusion arising from the circuits physical arrangement.

The series capacitor commutated circuits shown in *Fig. 6A* and *6B* have essentially the same wave forms. These approaches are capable of high efficiency even though they only incorporate a single controlled rectifier. For proper commutation the circuit containing the controlled rectifier must be a fast time constant circuit compared with the other circuit. This causes the load voltage to contain relatively large even harmonics.

Perhaps some comparison of series and parallel commutation will be helpful. In the case of series capacitor commutation there will be an excessive commutating angle and *kva* for low resistive loads, while for high resistive loads there will be insufficient commutating voltage. These conditions are just reversed in the parallel capacitor commutation circuit. In general the choice between the two approaches will depend on the wave form desired and the load requirements. It is possible to obtain a fairly square wave with resistive loads, approaching the saturating core transistor circuit in the parallel case with very little commutating *kva*. *Fig. 4C* shows the anode-cathode waveforms for these values of commutating angle. Notice the change in wave shape as a function of angle. The actual load voltage can be predicted from this plot. When the commutating capacitor is located directly across the controlled rectifiers the magnitude of the negative ordinate should equal the positive value at the end of the blocking period. When the capacitor is located elsewhere this is not exactly true. For inductive loads, the commutating *kva* requirements will be increased and the waveform will improve as the load and capacitor oscillate up. In the series capacitor commutated circuit, one is forced to operate with sufficient *kva* so that relatively good wave shape results, and it is not easy to get a square wave of output.

[*To be continued*]

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Hypersensitive Voltage Variable Capacitor*

HENRY D. FRAZIER**

A voltage-variable capacitor, referred to as "hypersensitive" is described. This type of device is new in that it is one-dimensional, with hypersensitivity obtained by the use of high-gradient, diffused, impurity distributions. It is also new in that very high Q values are possible with the method of fabrication. The Q values are highest at the lowest capacitance value. Since the Q values are high, while a wide range of capacitance values is obtainable, circuit engineers will find interest in their potential use in parametric amplifiers, *afc-fm* electronic tuning, and dielectric amplifiers. The fabrication methods involving three diffusions and micron-thick layers are described.

VOLTAGE-VARIABLE semiconductor capacitors have become important, both as passive capacitors for electronic tuning, *afc*, and modulator applications and as the active element in diode parametric amplifiers and harmonic generators. The performance of such diodes is dependent on the voltage sensitivity of the capacitance and the Q of the capacitor. Simple *p-n* junction capacitors, in general use, have a capacitance inversely proportional to either the cube root or the square root of the applied voltage.

The graded junction requires a 1000-1 bias voltage change to produce a ten-to-one change in capacitance. The abrupt junction requires a 100-to-1 voltage ratio for this capacitance change. Higher sensitivities (and

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**Pacific Semiconductors, Inc. (Research and Development Department)

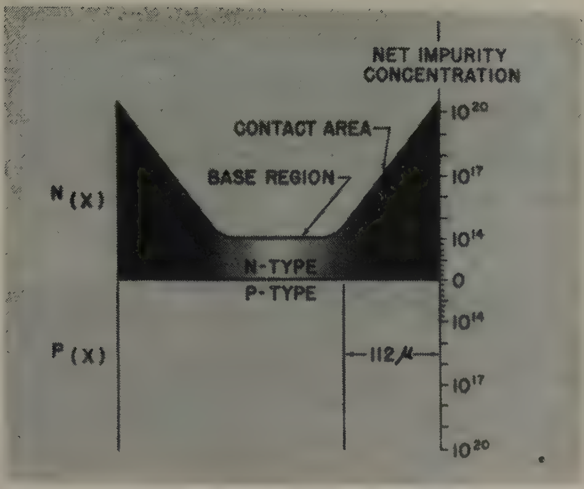

Fig. 1—Back contact diffusion.

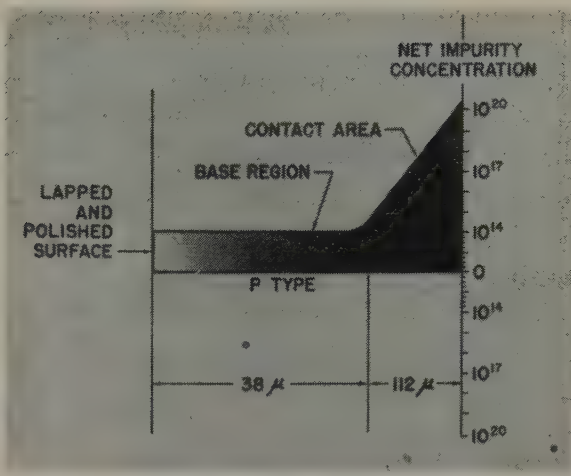

Fig. 2—One half wafer.

higher *Q's*) may extend the application of diode capacitors to further uses in such systems as parametric amplifiers, electronic tuning, *fm* modulation, and *afc* circuitry.

A capacitor diode is described here which exhibits a more rapid change of capacitance with voltage; the capacitance is approximately inversely proportional to the first power of the applied voltage. The developmental target was a capacitor with a ten-to-one capacitance change with a voltage swing from one to ten volts and a *Q* of at least 50 at 50 *mc*.

In order to achieve this target it was necessary to establish (1) an active region to produce the hypersensitive characteristic; the active region was chosen to be a reverse-gradient $n+$ region, thin enough to be completely swept by the depletion region at a voltage less than would cause breakdown; (2), a *p* region thin enough to provide an abrupt junction; and (3), a low resistance path to the active region from both directions.

These devices were made by diffusion techniques entirely, as far as the development of the capacitance properties is concerned. The following is a description of the fabrication method. The starting material was an *n*-type wafer, diagramatically shown in *Fig. 1*, of silicon of 10-15 ohm-cm resistivity into which a deep $n+$ diffusion has been established. The right-hand scale of this figure represents the impurity concentration in the silicon in atoms/cc. The horizontal scale represents the depths of the concentration levels within the silicon wafer. The scales must of necessity be distorted to allow for a modified logarithmic exhibition from zero to 10^{20} in two directions, in order to display a two micron thick layer as well as a 112 micron layer. In the next few figures, the right-hand side of the representation is the same. The 112 micron diffused layer is only for the purpose of reducing the resistance in series with the capacitor, while serving as a support for the very thin layers. Many similarities between this structure and a diffused transistor will be noted.

Since the starting $n+$ diffusion penetrates both faces of the wafer, one face must be removed to expose a proper thickness layer of the original material. *Fig. 2*, represents the wafer after one-half has been removed and the resultant face lapped and polished.

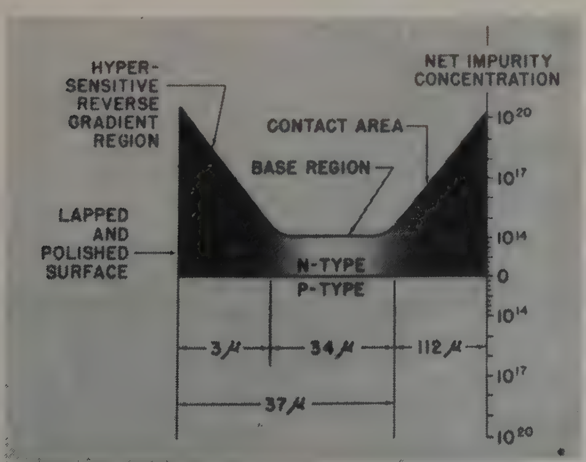

Fig. 3—Reverse gradient diffusion.

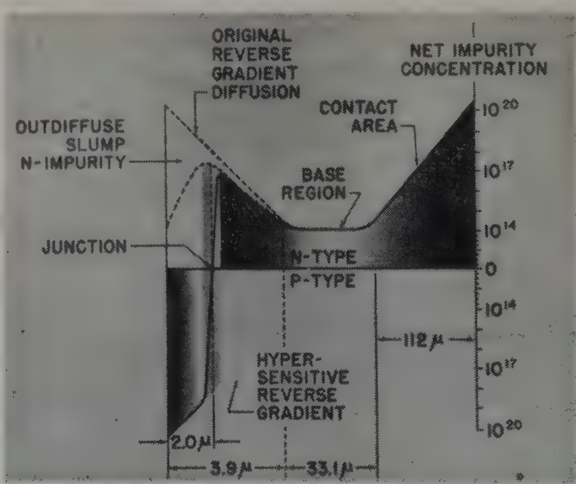

Fig. 4—Depletion region.

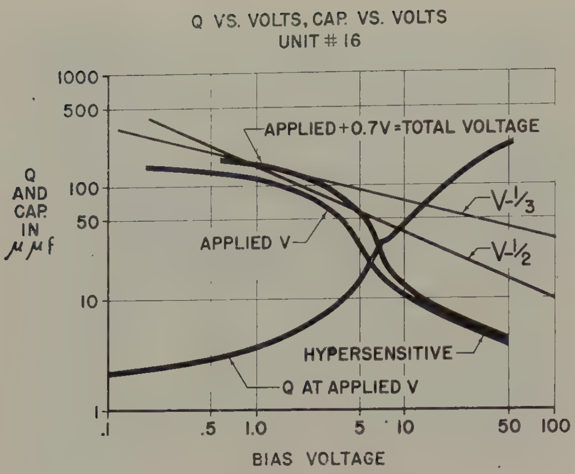

Fig. 5—Device characteristics.

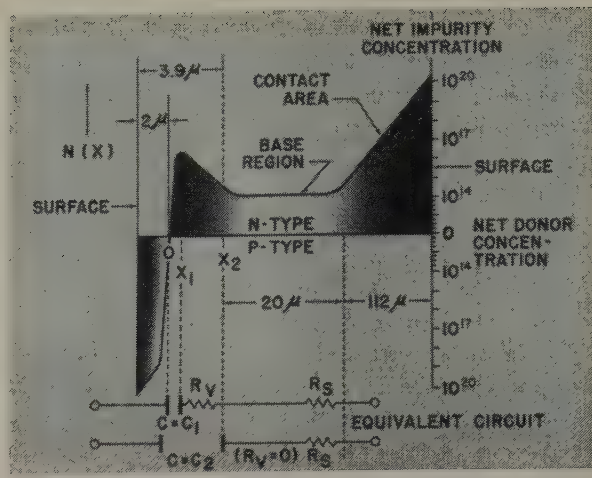

Fig. 6—Physical model.

Note that the left-hand of the distance scale is now expanded to allow a detailed view of the thin layers.

Next, another $n+$ diffused layer is established in this front-polished face so that the total depth is about three microns. This is shown with a scale expansion that makes the three micron layer about the size of the 112 micron layer of the back contact in *Fig. 3*. This thin $n+$ layer will provide the reverse gradient over which the depletion layer will sweep upon application of reverse bias, and is therefore referred to as the "hypersensitive $n+$" layer.

The depletion region is established so as to accomplish this as shown in *Fig. 4*. A $p{+}$-type region is formed by diffusion into the polished "front" face while the "back" is masked. While this $p+$ layer is being diffused, the hypersensitive $n+$ layer outdiffuses and slumps, i.e., its maximum concentration decreases. The original doping distribution is shown as the upper dotted line; the resultant $n+$ doping concentration is shown as the lower dotted curve; and the resultant net concentration is shown as a solid line passing through zero at the junction point. A depletion region exists on either side of the junction due to the built-in contact potential. Since the $p+$ layer is very heavily doped, the depletion region develops almost entirely in the hypersensitive $n+$ region, and since the resistivity is rapidly increasing as the region is swept, the depletion region expands much more rapidly than would be the case if the resistivity were constant. When the depletion region finishes sweeping the hypersensitive region at high bias, the device reverts to the $V^{-1/2}$ capacitance relation until breakdown occurs. The exact relationship of capacitance to voltage depends upon the distribution of the impurity atoms in the hypersensitive region and theoretically can be made as steep as desired, within the limits of diffusion distribution characteristics.

Fig. 5 shows the characteristics obtained for devices made in this way. By way of comparison, a $V^{-1/3}$ line, a $V^{-1/2}$ line, and the hypersensitive line are shown. It is easy to see the drastically different sensitivity obtained. The region in which the sensitivity reverts to $V^{-1/2}$ is shown as the lower end of the curve, and the capacitance goes through a ten-to-one change in eight volts. The Q characteristic of this particular unit was well explored, and the other line shows how Q varies as the bias and capacitance change, from a Q of three at high capacitance to above 200 at the lowest capacitance values. This unit was by no means optimized, since thinner base regions are possible. The base region of this diode was about 33 microns thick.

The Q variation can best be understood by study of *Fig. 6* in which are shown the various series resistances involved. It can be seen here that R_V cannot be avoided; this is the resistance of that portion of the hypersensitive region which is not in the depletion layer at a given voltage. The value of R_V can be varied, depending on the bias voltage and the steepness of the capacitance response to voltage. The parasitic resistances of the unused base region, the contacts, and the leads can be reduced by good design.

The absolute capacitance can be varied by choice of the size of the dice. The Q relationship is:

$$Q = 1/2\pi fRC$$

where $f =$ frequency in cycles/sec,
$R =$ the total resistance of the device in series with the capacitor,
and $C =$ the capacitance in farads.

The Q varies as $1/RC$; as dice size is decreased, the resistance goes up and the capacitance goes down, so that Q remains the same for different dice sizes.

Fig. 7 is a diagramatic picture of the finished die, ready for mounting and encapsulation, with a metallized surface on the p-diffused layer. *Fig. 8* is a picture of the finished hypersensitive unit showing the relative size and shape of the units that may have capacitance values as high as 500 μμf and as low as one μμf in the same size package.

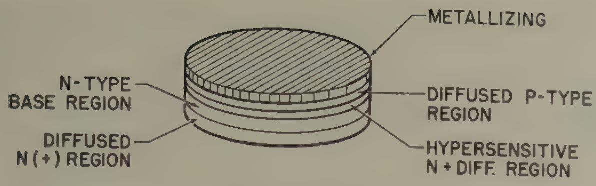

Fig. 7—Hypersensitive capacitor.

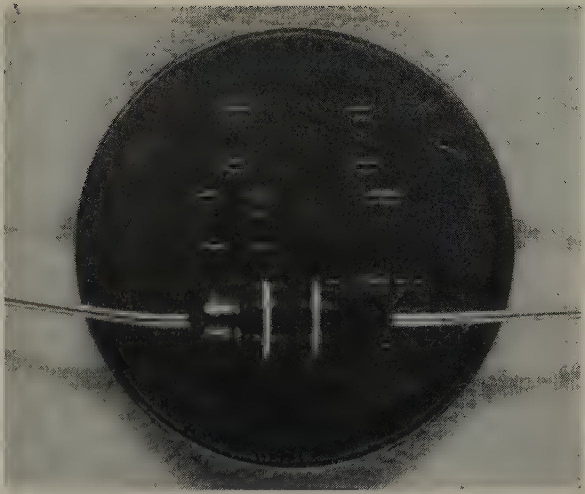

Fig. 8—Finished hypersensitive unit.

Fig. 9 is a plot of a special diode type which shows the versatility of the method. This unit has a long section which has 18 μμ*f* change of capacitance per volt applied bias, in a linear relationship to the applied voltage, and goes through a five-to-one change in five volts.

A method of achieving high voltage sensitivity was described earlier in a paper by C. J. Spector of Bell Telephone Laboratories in May, 1959 entitled "Fast Variable Junction Capacitors." This method employed a mechanically formed structure of silicon, causing the junction area to decrease with increasing bias voltage.

In conducting development work on abrupt junction alloy capacitors prior to the hypersensitive work, a method was discovered that made possible the fabrication of large quantities of $V^{-1/2}$ units having Q values over 200 at 50 *mc* and capacitance values of 10 to 47 μμ*f* (all values quoted at —4 volt bias). While these are manufacturable, the hypersensitive units are not yet beyond the laboratory stage. The fabrication of these diffused structures has been demonstrated, but further process engineering is needed before a high degree of control of the characteristics can be achieved.

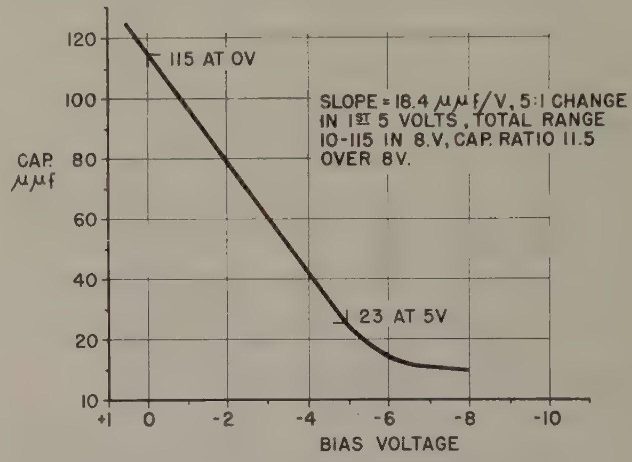

Fig. 9—Capacity vs. Volts for unit no. 749.

Junction Transistor Measurements And Practical Standards

BERNARD REICH* WILLIAM ORLOFF*

Part 1

Measurements and circuits required for the specification and evaluation of junction transistors have been set forth. The report covers the basic measurements required on most transistors, and specific techniques and circuits for *vhf* and *uhf* devices.

THE TITLE OF THIS ARTICLE would be more appropriate for an editorial than for a technical discussion of methods of evaluation currently being applied to transistors. Over the past ten years, the growth of standards in terms of applicable measurements, specifications, and packaging has not nearly kept up with a rapidly moving "state of the art." As a result, many individual specifications are generated which are redundant, not in description, but in device application. This is clearly indicated by issuance of many individual specifications for devices which

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perform identical functions. However, this situation is understandable in the light of changing device processes resulting in differences in manufacturer specification and requirements imposed by the user to meet specific circuit needs in an infant stage of many developments.

At the U. S. Army Signal Research and Development Laboratory, basic specifications necessary for the evaluation and characterization of semiconductor devices are developed. These specifications cover transmission and switching devices of both germanium and silicon material. Based on increased experience in specification preparation and a greater familiarization of device application, specifications are constantly being revised to present the most information in terms of the fewest number of tests. As yet, the industry has not been able to set down stereotyped conditions for the specification and measurement of transistor parameters for reasons previously mentioned. However, the circuit designer in order to understand the device he examines, must be familiar with current practices in the transistor industry. As a result of the experience gathered over recent years, this article is presented to serve as an interim status report on transistor measurements and practice standards, and to provide supplementary information from various sources in the industry. It is hoped that the article will also serve as a guide to the many engineers constantly preparing specifications on transistors.

Available Background Information

Background information on semiconductor standards and test methods exists in documents published by the military, the industry, and the *IRE*. A basic military document covering transistor tests and standards was MIL-T-19500A. Recently MIL-S-19500B has been issued which covers both transistors and diodes, and also reflects changes in testing and standard procedures for semiconductor device testing which have occurred since the issuance of MIL-T-19500A. These are commonly referred to as "basic sections." A basic document for transistor measurement was published by the *IRE* in the November 1956 issue of the Proceedings.(1) A subsequent article for testing point contact transistors in large-signal applications was printed in the May 1958 issue of the Proceedings.(2) At this point, measurement methods of junction transistor parameters will be discussed. It is not the intent of this article to develop analytical expressions covering the behavior of these parameters. References will be given to any analytical expression used in the course of the ensuing discussion.

Basic Transistor Measurements

Certain basic measurements are made on all transistors regardless of end application. These measured parameters are not always applicable to an end application, but it is sometimes necessary to specify characteristics to insure the purchase of a quality product. In the early days of junction transistor development, the basis for specification of devices were the small-signal hybrid parameters measured at 270 cycles/sec, subsequently 1000 cycles/sec. In the absence of direct information, this type of characterization sufficed for most specification needs. On the basis of specifications prepared within the past year, most of the "*h*" parameters in their audio frequency form are no longer applicable to all transistor specifications.

There are measurements which serve as the cornerstones for most transistor specifications. Some discussion and basic measurement circuitry will be presented on these fundamental parameters, and an indication as to their service in the specification will be shown. Of great importance to the device user is the $V_c - I_c$ transistor characteristic in the "on," "off," and "transition" regions. These characteristics are of great importance not only to the designer of audio amplifiers and switching circuits, but also to designers of large-signal *vhf* and *uhf* amplifiers and oscillators. There are two methods for accomplishing this end; one is to display the characteristic curves on an oscilloscope or chart recorder (the former being more acceptable); the other is to make point-by-point measurements. While both methods are used throughout the industry, most specifications feature points of measurement on various portions of the characteristic curves.

Diode Characteristics

One of the most important characteristics of the transistor is the status of the emitter and collector diodes. Associated with the status of these diodes are measurements of the cut-off currents or breakdown voltages. It is common to find in transistor military specifications many measurements on the status of both diodes. These tests are listed below with a brief description of their significance.

(a) *Collector or emitter cut-off currents, or collector to base, or emitter to base breakdown voltage.*

This test determines the condition of the collector to base or emitter to base diode and is in no way dependent on transistor action. When the breakdown voltage is measured it is commonly referred to as avalanche breakdown. As is common in transistor specifications either the collector or emitter cut-off currents are measured or the voltage under a specified current condition is measured. Depending on the type of the device being tested the range of current used varies from 100 μa to several milliamperes.

(b) *Collector to emitter breakdown voltage or collector current.*

This test may be made under a variety of conditions and usually brackets the voltage limits of the collector to emitter diode under operating conditions. The different conditions are outlined below.

(1) Base open

When the base of the transistor is open circuited and a voltage is applied between the collector and

emitter diode the collector current flowing is $I_c = (1 + h_{fe})\, I_{CBO}$ where h_{fe} is the common emitter current gain, and I_{CBO} is the leakage current of the collector-base diode. This value of I_C is normally specified on military specifications under a given voltage condition.

(2) Base Shorted

When the base of the transistor is shorted and voltage applied between the collector and emitter diode the problem encountered is the voltage developed across the extrinsic base resistance R_B'. As the voltage is increased and the leakage current increases the voltage developed across R_B' increases and is in a direction as to turn on the emitter base diode. This test therefore is primarily a measure of this resistance of the device.

Other conditions may be imposed on the base to emitter-diode of the transistor, i.e., back biased emitter-base diode or a finite resistance placed in series with the emitter base diode. However, because of rather limited use, these are not discussed.

A dilemma arises when we consider the conditions we are faced with in the measurement of the diode breakdown voltages. A typical method of specifying the manner of measurement is to indicate the value of reverse current supplied to a test transistor and measure the resultant diode voltage. When this is done, the voltage applied to good transistors inevitably exceeds the maximum voltage rating. The only way around the problem is to measure a collector cut-off current at a specified voltage which can arbitrarily be called a breakdown voltage.

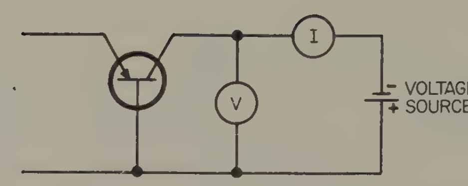
Figs. 1A and *1B* are the circuits commonly used to measure the diode cut-off currents or breakdown voltages. In *Fig. 1A* a constant voltage source is used and the current measured. In *Fig. 1B* a constant current source is used and the diode voltage measured. Although the test shown in *Fig. 1B* is not recommended the circuit diagram is illustrated for informational purposes.

Another measurement of importance to the transistor used for large-signal applications, is the saturation characteristic of the device. This characteristic, along with the diode characteristic, brackets the active region of the transistor. This is shown in *Fig. 2* where the three regions of the transistor output characteristics are shown. The importance of the saturation region is evident since the voltage drop across the transistor in saturation determines the power dissipated in the device in this condition as follows:

$$V_{CE\,sat} \times I_c = P_{diss\,sat.} \qquad (1)$$

Fig. 3 is the basic circuit used to measure this parameter and is accomplished by inserting a base current, I_B, in the base of the transistor such that the circuit gain is less than the normal *d-c* gain of the device.

Under this condition and with a constant collector current the voltage between the collector to emitter diode is measured. Also included in the circuit of



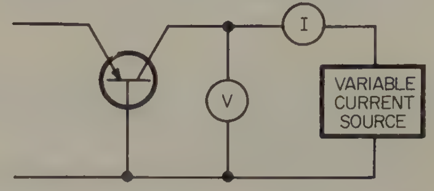


Fig. 1A (above)—Basic circuit used for measurement of the diode cut-off characteristics I_{CBO}, I_{EBO}, I_{CEO}, shown here is the measurement of I_{CBO}.

Fig. 1B (below)—Basic circuit used for the measurement of the diode breakdown voltages BV_{CB}, BV_{EB}, BV_{CE}, shown here is the measurement of BV_{CB}.

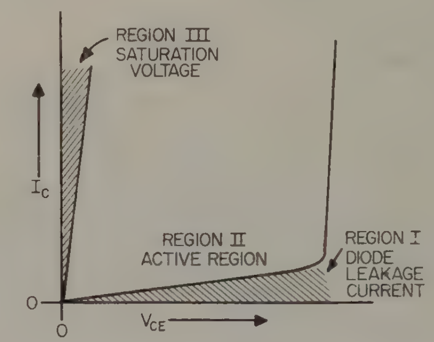


Fig. 2—Saturation, active and cut-off regions of the transistor.

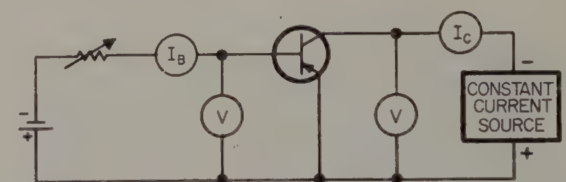


Fig. 3—Measurement of saturation voltage and input voltage.

Fig. 3 is provision for measuring the input voltage of the transistor when in saturation. This is a useful parameter in switching specifications. The above measurements essentially bracket the active region of the transistors' output characteristic. It is now necessary to indicate the measurements made in the active region of the device (Region II, *Fig. 2*). This measurement is the *d-c* large-signal current gain, h_{fe}, made at a low collector voltage, yet a high enough voltage to overcome the saturation voltage of the transistor. At the same time this measurement is made, the input voltage is monitored yielding a measure of the input impedance, V_{BE}/I_B, and the transconductance,

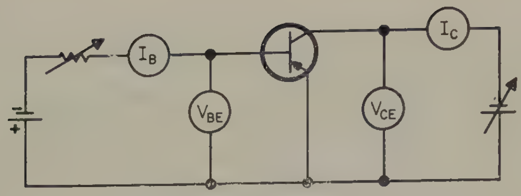


Fig. 4—Measurement of h_{FE} and V_{BE}.

I_C/V_{BE}. *Fig. 4* is the basic circuit used in the measurement of these parameters.

The description of the above measurements of basic transistor parameters completes the discussion on general measurements. In what specification are these measurements found? If the applications of transistors are broken into the groupings shown in Table I, then the applicability of these basic measurements to each function is indicated.

It is readily seen from Table I, that these parameters are quite universal and serve as the foundation of transistor specifications.

TABLE I

Application Of Basic Measurements To Transistor Specifications

Application	Diode Cut Off Measurements	Breakdown Voltage Measurements	Saturation Voltage	Large Signal Current Gain
General Purpose & Audio Transistors	X	X	X	X
Switching Transistors	X	X	X	X
Small Signal HF, VHF, & UHF Transistors	X	X		X
Large Signal HF, VHF, and UHF Transistors	X	X	X	X

Power Dissipation

Another parameter which is of importance to all applications of transistors is the power handling capability which is usually obtained from the measurement of the thermal resistance θ, also commonly called the *"K"* factor. The measurement of thermal resistance is made by utilizing one of the temperature sensitive parameters of the transistor as a thermometer. The details of this measurement can be obtained by referring to the two references cited below.[3,4] The power dissipation of the transistor can be calculated using the expression.

$$P_{diss} = \frac{T_J - T_a}{\theta_{ja}} \tag{2}$$

where T_j = junction temperature
T_a = ambient
θ_{ja} = thermal resistance between the junction and ambient.

From this expression it can be seen that for maximum dissipation the difference $T_j - T_a$ should be large and θ_{ja} small. Ideally the value of T_j can be determined by running a series of storage tests at various temperatures and choosing one temperature which yields the best life results. In practice, possibly for lack of better information, this concept is not universally accepted and operating life tests govern the maximum power dissipation. Further discussions on the subject of life testing will be presented in a subsequent portion of this report.

In dealing with power transistors it is often convenient to specify power dissipation in terms of the case temperature rather than the ambient. In this case,

$$P_{diss} = \frac{T_j - T_c}{\theta_{jc}} \tag{3}$$

T_c is the case temperature and θ_{jc} is the thermal resistance between the junction and case.

In expressions (2) and (3) θ_{jc}, θ_{ja} are used. These are related as follows:

$$\theta_{ja} = \theta_{jc} + \theta_{ca} \tag{4}$$

where θ_{ja} is the thermal resistance between the junction and ambient θ_{jc} is the thermal resistance between junction and case θ_{ca} is the thermal resistance between case and ambient.

Let us examine maximum power dissipation in the light of Equations (2) and (3) with an example. The following parameters of the transistor are given:

$$T_j = 100°\mathrm{C}$$
$$\theta_{jc} = 100°\mathrm{C/W}$$
$$\theta_{ja} = 250°\mathrm{C/W}$$

In addition we have the option of either operating at 25°C ambient temperature or clamping the case of the device to a large dissipator so that it remains at 25°C. Using Equations (2) and (3) we find the power dissipation to be

$$P_{diss} = \frac{T_j - T_a}{\theta_{ja}} = \frac{100°\mathrm{C} - 25°\mathrm{C}}{250°\mathrm{C/W}} = 0.3\mathrm{W}$$

$$P_{diss} = \frac{T_j - T_c}{\theta_{jc}} = \frac{100°\mathrm{C} - 25°\mathrm{C}}{100°\mathrm{C}} = 0.75\mathrm{W}$$

Using one transistor, two values of power dissipation are calculated, .75 watts or .3 watts, merely by choice of the method of mounting. Here lies a problem facing the industry whereby some manufacturers favor the more optimistic figure while others use the more conservative approach. In between these two numbers lies a whole host of power dissipation figures dependent on the type of dissipator used. In terms of the device, which we are attempting to specify only the thermal resistance between junction and case is important, the case to air thermal resistance is a function of both the case dimension and of the dissipator used.

At this point we digress from the d-c measurements on the transistor and consider other parameters which govern the behavior of the devices in specific circuit applications. These include such parameters as the collector capacitance, the critical *"h"* parameters measured for higher frequency circuit performance and alpha cut-off frequency.

Alpha Cut Off Frequency And f_T

The alpha cut-off frequency is defined as the frequency at which the magnitude of the current gain falls 3 *db* from its low frequency value. Commercial equipment has been developed which essentially displays the value of alpha as a function of frequency, yielding the value of the alpha cut-off frequency. In addition other less elaborate equipment can be used in measuring this parameter as illustrated in *Fig. 5*. In *Fig. 5, R1* is much greater than h_{ib}, the short circuit transistor input impedance, to insure a constant current input, i_e. The output current, i_c, can be measured as the voltage drop across $R2$. In this manner $\alpha = i_c/i_e$ is measured as a function of frequency and when alpha falls to .707 α_0, the frequency is the alpha cut-off frequency. The measurement of this parameter, either by the display technique or the point by point technique is not practical above 50 megacycles/second.

With the advent of higher frequency transistors such as the drift, *mesa* and *madt* types, it has become necessary to adopt other techniques to measure the frequency response of transistors. To understand this new technique we examine *Fig. 6* which is a plot of the variation of common emitter current gain, h_{fe} as a function of frequency. The point at which the gain falls to zero decibels is designated as the f_T frequency. The characteristic of this curve is the 6 decibels/octave fall-off with frequency culminating in the f_T frequency. By virtue of the 6 *db*/octave fall-off it can be shown that

$$h_{fe} \times f = f_T \tag{5}$$

where h_{fe} is the short circuit current gain measured on the 6 *db*/octave portion of the curve and f is the frequency of measurement. This technique necessitates the measurement of short circuit current gain at the proper frequency. *Fig. 7* is the circuit used to measure this parameter.

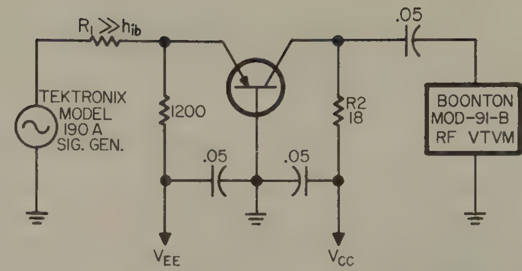


Fig. 5—Measurement of alpha cut-off frequency, all resistors non-reactive high frequency type, output level is set at 3 millivolts rms.

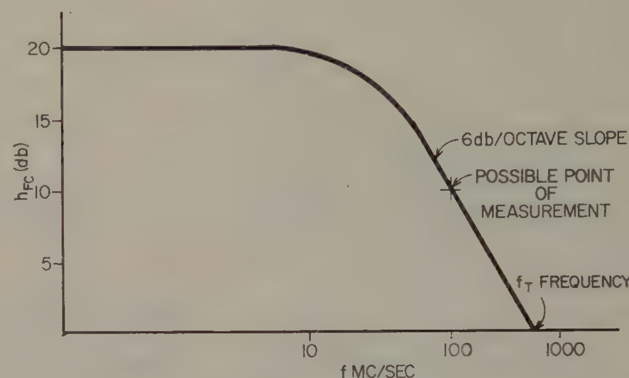


Fig. 6—The variation of small signal current gain with frequency.

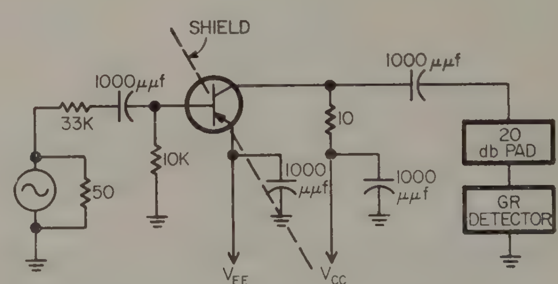


Fig. 7—Measurement of small signal short circuit current gain, h_{fe}, all resistors h.f. non-reactive type.

(To be continued)

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Applications Engineering Digests

APPLICATIONS ENGINEERING DIGEST NO. 30

Applying Thermal Characteristics of Silicon Diodes; Hoffman Electronics Corp., Evanston, Illinois.

Introduction

Most of the electrical characteristics of semiconductor devices are temperature sensitive. While the variation of device characteristics with temperature is usually considered undesirable it enables one to measure in a very simple way such device properties as thermal resistance and thermal time constants. These "application notes" will discuss the origin of the temperature variation of device characteristics. A subsequent article will discuss how certain temperature dependent characteristics can be combined to produce a unit whose properties are relatively temperature insensitive, and typical applications using the thermal characteristics of silicon diodes.

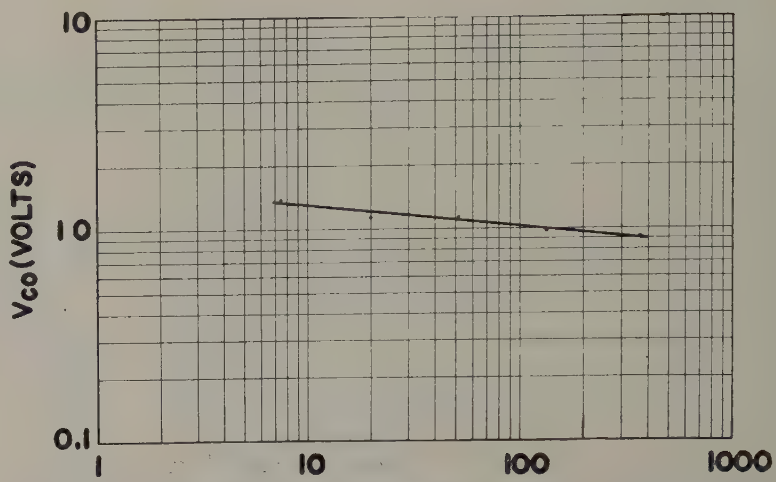

Fig. 30.1—Forward voltage drop corresponding to the cross-over current (V_{co}) as a function of the nominal Zener breakdown voltage for some Hoffman IN200 series diodes.

Forward Biased Diodes as Low Voltage Reference Devices

The forward characteristic of a silicon diode has a negative temperature coefficient (i.e., the forward voltage for a given forward current decreases with increasing temperature) for sufficiently low forward currents. As the forward current is increased the temperature coefficient decreases in magnitude to zero and then changes sign and increases. This behavior is due to the positive temperature coefficient of resistivity of silicon over the range of temperature usually encountered in practical applications. The forward current at which the temperature coefficient vanishes is a function of the resistivity of the base silicon and the geometrical configuration of the diode. At this current the forward characteristic curves corresponding to different temperatures cross one another and the forward voltage drop corresponding to this cross over current is relatively insensitive to temperature. The forward voltage drop at the cross over current is plotted as a function of the nominal "zener" voltage for the Hoffman IN200 series of diodes in *Fig. 30.1*. *Fig. 30.2* shows the cross over current as a function of "zener" voltage for the same series of diodes. As may be seen from *Fig. 30.1* the voltage drop corresponding to the cross over current is of the order of one volt. Therefore, to achieve high reference voltages one must put two or more diodes in series. The voltage obtained from such series combinations of forward biased diodes overlaps the range of zener voltages obtainable for silicon aluminum alloy diodes. Since the forward impedance of the diodes would be additive, one might expect the series string to be a poorer regulator than a single reverse biased diode of the same voltage.

Stability of Reference Units

The stability of the characteristics of these units with time has been exhaustively treated elsewhere. However, since their use in certain critical control applications depends on this stability, typical output voltage versus time curves are shown in *Fig 30.3*. The results are normalized in such a way that the positive and negative changes in output voltage from the initial 25°C value are plotted as a function of time under various operating conditions.

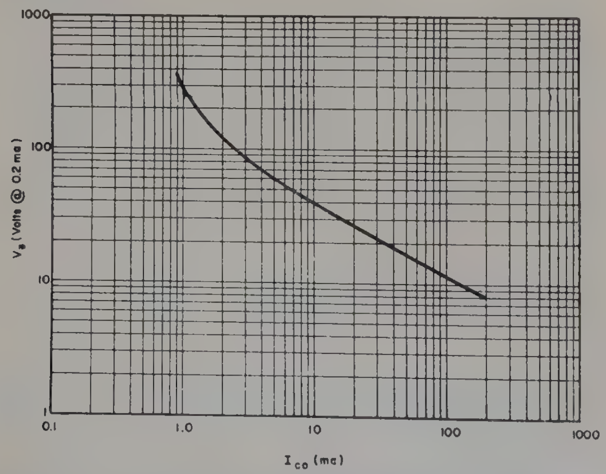

Fig. 30.2—Cross-over current for the Hoffman IN200 series of alloy diodes as a function of their nominal Zener breakdown voltage.

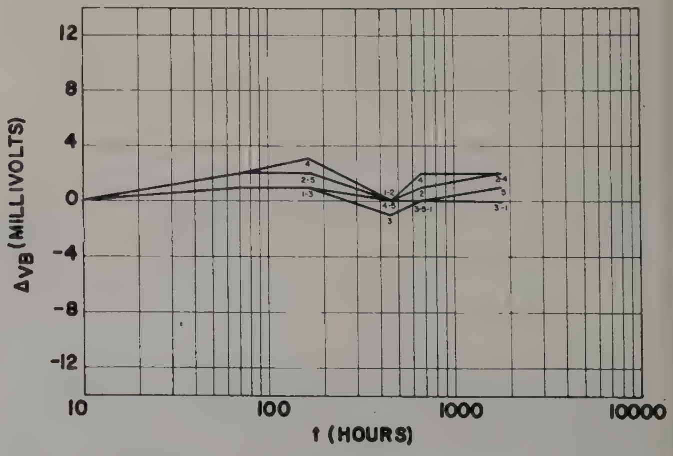

Fig. 30.3—Change in nominal output voltage versus time for some IN430 diodes under various operating conditions.

APPLICATIONS ENGINEERING DIGEST NO. 31

Transistors as Switches; Texas Instruments Incorporated, Dallas, Texas.

Importance of Propagation Time

The importance of propagation time is illustrated by *Fig. 31.1,* where four identical transistor switches are placed in cascade.

Stages 1 and 3 are *off;* stages 2 and 4 are *on.* If the input changes stage 1 to *on,* the other stages likewise are changed. The output from 4 will not occur until a time equal to 2 T_T after the input is applied to stage 1. If the output of stage 4 were to be coincident in a gate with the input to stage 1, the gate must be held *on* to accommodate the large time difference of 2 T_T. Thus, the speed at which information can be propagated is limited by T_T. T_T for present saturated transistors is usually 100-150 mμsec.

To improve T_T, if all stages were non-saturated stages, transistors with a higher frequency response could be substituted. This would cause both t_r and t_f to decrease and T_T accordingly. However, if all the stages are saturated switches, it is not sufficient to merely substitute transistors with higher frequency response. Even though t_r and t_f would be reduced, T_T may not be appreciably reduced because the storage time is still quite long. *High-frequency transistors must also have lower storage time to significantly reduce T_T.* A good figure of merit to compare saturated switching transistors is the T_T obtained when the transistor is used in a given saturating circuit where I_{B1}, I_{B2}, and I_C are set values in the circuit. (Note that $V_{BE(OFF)}$ should also be constant to keep t_s variations at a minimum).

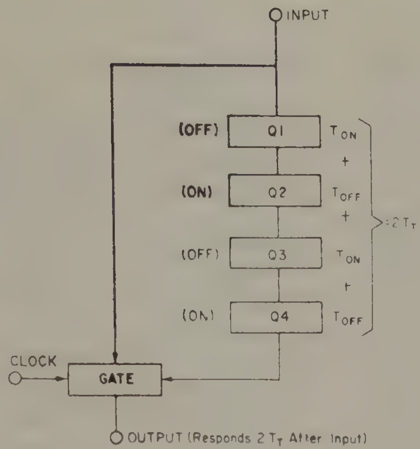

Fig. 31.1—Propagation time.

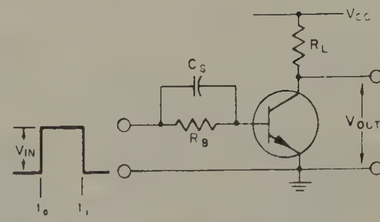

Fig. 31.2—Common emitter configuration.

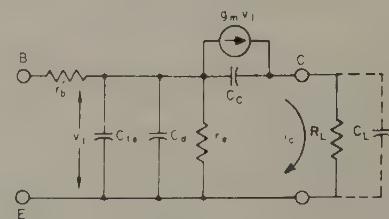

Fig. 31.3—Saturated switching circuit.

Importance of the Type of Drive

If a step of voltage is applied to the base-emitter input (*Fig. 31.2*) from a generator with source resistance R_g, v_1 is present immediately (restricted only by r'_b and R_g) and i_c responds quickly. The amount of overdrive is determined by v_1. If the same type of voltage drive is now used to turn-off the transistor, the minority carriers stored in the base are swept out quickly and i_c again responds quickly. The fastest response is obtained from a switching transistor by using low-impedance voltage-drive generators.

The saturated switching circuit shown in *Fig. 31.3* has a "speed-up" capacitor across the large resistor in series with the base. The circuit applies constant current drive to the transistor during the steady-state operation, but during the switching transient, the capacitor is essentially a low impedance and the drive is really a voltage drive. The speed-up capacitor reduces the total switching time considerably.

Circle 198 on Reader Service Card

APPLICATIONS ENGINEERING DIGEST NO. 32

Transistor Inverters; Varo Mfg. Co. Inc., Garland, Texas.

Figure 32.1 illustrates an inverter output stage in which transistors are employed as switches. *Fig. 32.2* shows the same circuit with controlled rectifiers used as switches.

The choice between the two different types will depend upon the application. Since the transistor requires that the driving source be of the square wave type in order to hold the transistor *"on"*, then more *average* drive power is needed. The fact that the transistor *will* turn *"off"* when the driving source goes to zero, however, gives the transistor a distinct advantage in that the output voltage may be controlled by varying the conduction angle (on time) of the transistor. A simplified block diagram of a precise-frequency switching-transistor inverter with output voltage regulation is illustrated in *Fig. 32.3.*

The Varo tuning fork oscillator furnishes a precise frequency square wave to a conduction-time control. The output of the control is a wave where the conduction angle Θ is controlled by the action of an error signal to furnish a symmetrical wave as shown.

Circle 199 on Reader Service Card

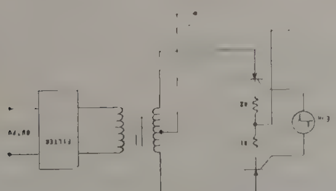

Fig. 32.1—Simplified output stage parallel transistor inverter.

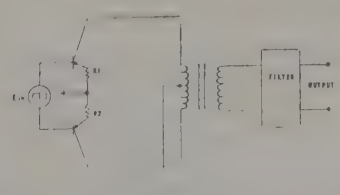

Fig. 32.2—Simplified output stage parallel diode inverter.

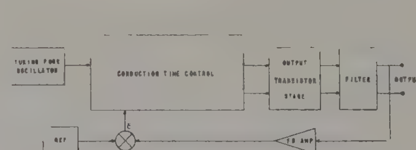

Fig. 32.3—Block diagram for regulated transistor inverter.

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Restoration of the Parameters of Germanium Subjects to Thermal Treatment by Annealing in Vapors of Antimony and Arsenic	Sov Phys Sol State Vol 1 No 4 1959	Restoration of the original properties is possible by a prolonged annealing by annealing in metals and by an electric field while passing current.	N. L. Chetverikov
Photomagnetic Effect in Single Crystals of *n*-type Indium Antimonide	Sov Phys Sol State Vol 1 No 4 1959	The transverse photomagnetic effect in high-purity single crystals of *n*-type InSb was studied.	D. N. Nasledov, Yu. S. Smetannikova
Pecularities of the Electrical Properties of Continuous Solid Solutions in the Te-Se and Te-S Alloys	Sov Phys Sol State Vol 1 No 4 1959	A detailed study is made of the dependence of a number of properties of the Te-Se and Te-S alloys on the composition.	V. N. Lange, A. R. Regel'
The Problem of Electrical Properties of Gallium Arsenoselenides	Sov Phys Sol State Vol 1 No 4 1959	Measurements are made of electrical conductivity at different temperature, and thermal *emf* of different compositions of this system.	D. N. Nasledov, I. A. Feltin'sh
Certain Properties of the InSbGaSb Alloy	Sov Phys Sol State Vol 1 No 4 1959	Preliminary results are given of electrical and optical measurements made on this alloy.	V. I. Ivanov-Omskii, B. T. Kolomiets
Electrical Properties of *p*-type InSb at Low Temperatures	Sov Phys Sol State Vol 1 No 4 1959	The specific electrical conductivity and the Hall constant were measured on various specimens in a temperature range from 300 to 4.5°K.	Lien-Chih-Ch'ao, D. N. Nasledov
The Theory of the Mobility of Electrons in Semiconductors	Sov Phys Sol State Vol 1 No 4 1959	Scattering of electrons by Coulomb centers in an anisotropic medium is considered using the Born approximation.	L. I. Boiko
Regarding the Effect of Surface Treatment on Some Properties of the Photoconductivity of CdS Monocrystals	Sov Phys Sol State Vol 1 No 4 1959	Results are given which were obtained with CdS crystals subjected to a treatment in the glow-discharge, and to a short-duration heating in air.	E. A. Sal'kov, G. A. Fedorus, M. K. Sheinkman
Effect of the State of Surface of PbS and CdS on the Contact Potential Difference	Sov Phys Sol State Vol 1 No 4 1959	Investigations are made relative to platinum or gold; also change with irradiation, oxidation, and under the influence of a magnetic field.	L. P. Strakhov
Photoelectric Properties of Semiconductor Rectifying Elements in X-Rays	Sov Phys Sol State Vol 1 No 4 1959	Experimental investigation of the action of X-Rays on selenium rectifying elements used as photodiodes and as photovoltaic cells.	I. G. Nekvashevich
Concerning the Dependence of the Reverse Current in a Germanium Diode on the Repetition Rate of Voltage Impulses	Sov Phys Sol State Vol 1 No 4 1959	The influence of surface treatment of *p-n* junctions on the magnitude of reverse current, and the breakdown voltage of DGTs diodes is investigated.	S. G. Shulman
An Investigation of the Diffusion of Zn and Se in Be_2 Se_3, BiSe and CdSb	Sov Phys Sol State Vol 1 No 4 1959	Activation energies of zinc in various compounds differ. These differences are discussed and evaluated.	A. A. Kuliev, G. B. Abdullaev
On the Calculation of the Diffusion Coefficient in Solids	Sov Phys Sol State Vol 1 No 4 1959	An analysis of some of the systematic errors which occur during a determination of diffusion.	R. Sh. Malkovish
Stability of Piezoelectric Effect in Compressed Barium Titanate	Sov Phys Sol State Vol 1 No 4 1959	The piezoelectric effect is well preserved over long periods of time. Prolonged heating at 70°C; subjecting the material to an electric field has little effect on the piezoelectric modulus.	M. M. Kitaigorodskii
The Efficiency of Refrigeration Thermocouples	Sov Phys Sol State Vol 1 No 4 1959	It is shown that the thermoelectric efficiency is a function of the temperature drop across the thermocouple.	E. K. Iordanishvili
A Simple Transistor Test Set	U S Govt Res Repts July 17 1959 OTS $0.50 PB 151300	A small transistor test set was designed to measure I_{co}, I_{EO}, and H_{FE}.	H. V. Wood
Component Evaluation and Specification Engineering: Task XI. Temperature Element, Thermistors	U S Govt Res Repts July 17 1959 LC $44.10 PB 139990	Performance of rod, disk, and bead thermistors as affected by low-temperature storage, moisture resistance, temperature cycling, shelf-life and continuous-load life.	W. E. Chapin, P. G. Perry

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Special Measurement Techniques for Thermoelectric Materials with Results for Bi_2Te_3 and Alloys with Bi_2Se_3	U S Govt Res Repts July 17 1959 OTS $0.50 PB 151656	A new technique for accurate measurement of the thermoelectric power and thermal conductivity.	T. C. Harman M. J. Logan
High Frequency Compensation of a Drift Transistor	U S Govt Res Repts July 17 1959 LC $4.80 PB 139949	Given a desired frequency response, it should be possible to synthesize an infinite RLC ladder of non-identical elements.	S. Deutsch
Unilateralized Common Collector Transistor Amplifier	U S Govt Res Repts July 17 1959 LC $4.80 PB 136671	A three-terminal transformerless unilateralized common collector amplifier is discussed.	L. M. Vallese
Transistor Crystal Oscillator Circuitry	U S Govt Res Repts July 17 1959 LC $24.30 PB 139070	Step-by-step design data sheets are given for four common circuits and are followed by six specific design examples.	W. McSpadden R. J. Shedko T. G. Evans
Study of Parametric Amplification	U S Govt Res Repts July 17 1959 LC $4.80 PB 140143	Parametric amplifiers employing semi-conductor junction diodes as non-linear capacitors have been studied theoretically and experimentally.	E. E. Bell Y. P. Vaddiparty
Intrinsic-Barrier Transistor Techniques (Silicon)	U S Govt Res Repts July 17 1959 LC $7.80 PB 138833	Comparative design data, transistor fabrication, and transistor fabrication, and transistor terminal characteristics.	J. L. Buie
A Study of Avalanche Transistors	U S Govt Res Repts July 17 1959 LC $21.30 PB 140108	The simultaneous occurrence of avalanche multiplication and voltage punch-through produces either large current pulses or pulses with very fast rise time.	D. S. Gage
A Transistorized Linear Sweep Circuit	U S Govt Res Repts July 17 1959 LC $10.80 PB 139848	Study of a linear sweep generator composed of a triggered gate generator and a bootstrap circuit.	E. F. Yhap
Power Transistor Circuitry	U S Govt Res Repts July 17 1959 LC $9.30 PB 140106	Power supplies had multiple output voltage requirements ranging from 6V to 650V. All required regulation against line voltage variation.	R. H. Packard
The Study, Analyses and Design of Transistor Circuits	U S Govt Res Repts July 17 1959 LC $4.80 PB 139422	Part I: Investigation of the high current mode of operation of transistors, and circuit applications. Part 2: Investigation of pulse generating circuits producing extremely short duration pulses.	Transistor Applications Inc.
Study of Properties of Single CdS and ZnS Crystals for Use as Detectors in Crystal Counters	U S Govt Res Repts July 17 1959 LC $9.30 PB 136471	Analysis of various methods of describing electronic charge distributions and conclusions as to the most sensitive methods.	S. J. Czyzak
The Conductance of a Cleaned Germanium Surface	U S Govt Res Repts July 17 1959 LC $13.80 PB 139998	Conductivity and field effect mobility of the carriers in the region of the space charge of a cleaned germanium surface were measured as a function of various gas ambients and temperature.	W. Portnoy P. Handler
Eect of Ion Bombardment on Semiconductor Surfaces	U S Govt Res Repts July 17 1959 LC $16.80 PB 139999	Measurements of surface properties of etched germanium surfaces were carried out before and after bombardment by 500 and 1000 volt oxygen ions.	S. R. Arnold
Studies on the Mechanisms of Electroluminescence	U S Govt Res Repts July 17 1959 LC $4.80 PB 136566	ZnS single crystals were E.L. only after activation. The threshold of E.L. in the *a-c* field is of 500 volts/cm.	A. Luyckx J. Vandervauwer S. Ries
Effective Mass of Electrons in Gallium Arsenide	U S Govt Res Repts July 17 1959 LC $1.80 PB 138442	The effective mass of electrons in a sample of *n*-type gallium arsenide has been measured by determining the reflectivity in the infrared.	L. C. Barcus A. Perlmutter J. Callaway
Dipole Scattering in Semiconductors	U S Govt Res Repts July 17 1959 LC $1.80 PB 135161	Recent work on semiconductors suggested consideration of dipole scattering effects in these substances.	R. R. Slocum
Transmission Line Formulation for Semiconductors	U S Govt Res Repts July 17 1959 LC $1.80 PB 140019	A more suitable test function for the variational method of computing the scattering coefficient is given.	P. Parzen
Study of Surfaces in Semiconductor Devices	U S Govt Res Repts July 17 1959 LC $7.80 PB 139830	Experimental data is offered which indicate that the assumption of less than complete diffused scattering of carriers at the surface of silicon and germanium is more reasonable than the complete diffused scattering previously assumed.	T. C. Hall M. F. Millea
Effects of Temperature Gradients on Self-Absorption of Infrared Radiation in Hot Gases	U S Govt Res Repts July 17 1959 LC $4.80 PB 136052	The intensity distribution in the infrared emission spectrum of a hot gas stream depends to a large extent on self-absorption within the gas.	R. H. Tourin

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Sept. 3, 1957 to Oct. 15, 1957. In subsequent issues, patents issued from Oct. 15, 1957 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

September 3, 1957
2,805,133 Preparation of Pure Silicon—C. M. Olsen. Assignee: E. I. duPont de Nemours & Company. A process for preparing hyperpure elemental silicon by removing trace impurities from a relatively pure silicon halide, causing the halide, in a vapor state, to come into contact with a pure vaporized metal reductant maintained at a temperature above the dew point of the reductant and its reaction product, but below the melting point of the silicon in the chamber.

2,805,347 Semiconductive Devices—J. R. Haynes, J. A. Hornbeck. Assignee: Bell Telephone Laboratories. A device including a semiconductive body, a pair of ohmic electrodes connected to two spaced region on the surface of said body, means for injecting minority carriers into said body between said spaced regions, and voltage supply means and a load connected in series between said electrodes.

2,805,369 Semiconductor Electrode System—A. vanWieringen. Assignee: North American Phillips Co., Inc. A device comprising a granular, egg-shaped, semiconductive body of which the narrow head has a greater concentration of impurities than the opposite end, said opposite end having a planar portion and means for making rectifying contact and ohmic contact thereto.

2,805,370 Alloyed Connections to Semiconductors—D. K. Wilson. Assignee: Bell Telephone Laboratories. A semiconductive translating device comprising a silicon body and a mass of gold and aluminum containing about 0.1 percent to 2 percent by weight of aluminum alloyed with a portion of said body.

2,805,397 Semiconductor Signal Translating Devices—I. M. Ross. Assignee: Bell Telephone Laboratories. In a signal translating device, means for suppressing and controlling minority carrier flow in such a way as to modulate the output or load current.

September 10, 1957
2,805,968 Semiconductor Devices and Method of Making Same—G. E. Dunn, Jr. Assignee: Radio Corporation of America. A method of fabricating an electrical junction device by applying to one portion of a surface of a crystal semiconductor wafer a thin adherent film of magnesium hydroxide, and treating an adjacent film-free surface in order to form a rectifying barrier.

2,806,153 Electric Trigger Circuits—T. H. Walker. Assignee: International Standard Electric Corporation. A trigger circuit comprising a pair of crystal triodes, means for connecting both collector electrodes to a point of fixed potential, means for criss-crossing the base and emitter electrodes, means for applying an input pulse to one emitter to interchange the condition of the triodes, and means for deriving an output signal in response to the input pulse.

2,806,154 Circuit Arrangement to Change the Characteristics of Multielectrode Tubes—K. Steinbeck. Assignee: International Standard Electric Corporation. A circuit arrangement for sharpening the flanks of impulses comprising an electronic triode, means coupling the base electrode over a resistance to the cathode of the tube, means coupling the emitter directly to the cathode, and means for applying an input signal between the grid and the collector electrodes.

2,806,187 Semiconductor Rectifier Device—J. L. Boyer, W. S. Albert. Assignee: Westinghouse Electric Corporation. A semiconductor rectifier which is encapulated for protection against moisture and which is mounted in a finned structure for providing cooling.

2,806,188 Crystal Diode—J. J. Kastner, I. C. Mozina. Assignee: None. A device comprising a hollow shell having a semiconductor crystal mounted therein, a whisker in point-contact with the surface of said crystal, a body of dielectric material embedding the contact end of said whisker and said surface, and terminal means leading from said crystal and said whisker.

2,806,189 Alkaline Titanate Rectifiers—P. J. Dymon. Assignee: Sylvania Electric Products Inc. A rectifier comprising a reduced titanate of an alkaline earth metal having a double layer on one surface thereof, said double layer consisting of an electrolytically deposited metal oxide.

September 17, 1957
2,806,807 Method of Making Contact to Semiconductor Bodies—J. A. Armstrong. Assignee: General Electric Company. A method of forming electrical contacts to crystalline semiconductors by forming a pool of acid etching solution upon a surface thereof, placing a quantity of contact material in the pool and heating the semiconductor until the etching solution attacks both the semiconductor and the contact material.

2,806,929 Photo Sensitive Device—R. A. Langevin. Assignee: Clevite Corporation. A photosensitive device comprising two supporting leads, an elongated photosensitive member connected between said leads, and plastic supporting means encasing said semiconductive member and a portion of said leads.

2,806,961 Crystals with Small Apertures—F. H. Horn. Assignee: General Electric Company. A method of producing a crystal having a small hole suitable for serving as an aperture for pinhole beams in X-ray or electron defraction techniques.

2,806,964 Transistor Regenerative Pulse Amplifier for Power Applications—J. F. Spades, A. W. Carlson. Assignee: U.S.A. (Department of the Air Force); A plural stage transistor parallel regenerative pulse amplifier for use as an output stage in digital, or pulse circuitry, or wherever it is necessary to develop a voltage across a low output impedance.

2,806,983 Remote Base Transistor—R. N. Hall. Assignee: General Electric Company. *P-N* junction transistors which do not require contact being made to an extremely thin base region, and which exhibit a high order of current amplification.

2,806,984 Selenium Rectifiers and Process for Manufacturing the Same—W. Kock. Assignee: Licentia Patent—Verwaltungs—G.m.b.H. A method for manufacturing selenium rectifiers having at least two successively disposed selenium layers of different impurity content predominantly of halogen atoms.

2,806,989 Electronic Synchronous Converters—F. F. Shoup. Assignee: Radio Corporation of America. An electronic synchronous converter comprising two, two-junction, photo-conducting crystals, means for applying a voltage across one of the crystals, means for applying the radiation from a source of varying radiant energy to one of the crystals in order to chop said voltage, means for amplifying said chopped voltage, and means to apply radiation from a second source to the second crystal.

2,807,011 Fail-Safe Technique and System—W. G. Rowell. Assignee: Scully Signal Company. Switching apparatus that is adapted for use in installations where the terminal power supply is direct current.

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

September 24, 1957

2,807,558 Method of Sealing a Semiconductor Device—J. J. Pankove. Assignee: Radio Corporation of America. A method of sealing a semiconductor device by applying a back voltage across a rectifying barrier of value sufficient to generate heat and prevent moisture deposits, and coating said device with an insulating moisture-impervious inert material while maintaining said potential.

2,807,561 Processing of Fuzing Materials to Silicon—H. Nelson. Assignee: Radio Corporation of America. A method of fusing a conductivity-type determining material to a silicon surface bearing a film of silicon oxide, by heating said material and said surface in the presence of a fluoride salt.

2,807,718 Transistor Detector—A. G. Chressanthis, F. Mural. Assignee: Philco Corporation. A detecting circuit for amplitude modulated signals, said circuit utilizing a semiconducting device and being of such a nature that it does not appreciably attenuate the detected signal.

2,807,719 Electric Pulse Generators Employing Semiconductors—K. W. Cattermole. Assignee: International Standard Electric Corporation. A pulse generator or trigger circuit including one or more crystal triodes so designed that the operation is substantially independent of the characteristics of the crystal triode used.

2,807,758 Transistor Flame Detector—B. H. Pinkaers. Assignee: Minneapolis-Honey well Regulator Company. A transistor flame detector in which the emitter to base current is controlled by flame sensing means, and caused to pulsate continuously when flame is present; said device having a flame checking circuit to insure continued proper operation of the flame detector.

2,807,761 Current Rectifier Assembly—J. R. Thurell Jr. Assignee: General Electric Company. Current rectifying devices having cell assemblies that include a contact and spacer member independently secured to a rectifier cell by way of an insulating cell-mounting element.

2,807,762 Method of Producing Selenium Rectifiers—H. K. Strosche. Assignee: International Standard Electric Corporation. A method of manufacturing selenium rectifiers by applying a thin intermediate metallic layer to the selenium consisting of a metal having a large work function, and in which layer said metal does not exceed 5×10^{-7} gm/cm² before applying the counter electrode on top of said thin layer.

October 1, 1957

2,808,315 Processing of Silicon—G. Bemski. Assignee: Bell Telephone Laboratories. A method of manufacturing a single crystal silicon body and limiting the thermal degradation of the minority carrier lifetime of said body by cooling the crystal from a temperature greater than 400°C at maximum rate of 20°C per minute.

2,808,469 Transistor Circuit—R. P. Crow, J. A. Doremus. Assignee: Motorla, Inc. In a circuit, a transistor stage in which the input circuit has high impedance so that it is independent of the voltage drop across the input electrodes of the transistor and it is linear with input voltage.

2,808,471 Temperature Compensated Semiconductor Signal Amplifier Circuits—W. H. Poucel, J. W. Woestman. Assignee: Radio Corporation of America. A circuit which is stabilized with respect to temperature changes by connecting a temperature compensating "T" network with a transistor in such a manner that the effects due to changes of base saturation current with temperature variation are compensated for.

2,808,523 Crystal Assembly—J. D. Holmbeck. Assignee: The James Knights Co. A crystal assembly comprising an evacuated hermetically sealed envelope, a crystal mounted in said envelope, two conductive loops within said envelope, said loops having their axes at right angles to one another, an amount of vaporizable metal on one loop, and a shield partially surrounding the metal and having an opening for directing vaporized metal toward the crystal.

2,808,543 Mounting Means For Semiconductor Crystal Body—T. W. Cooper. Assignee: Hughes Aircraft Company. Means for mounting a semiconductor crystal body in an encapsulated device which isolates the region of the diaphragm upon which the crystal is mounted from excessive stresses, shocks, and strains.

October 8, 1957

2,809,103 Fabrication of Semiconductor Elements—B. H. Alexander. Assignee: Sylvania Electric Products Inc. A means for preparing a germanium crystal for use by etching the crystal in a bath of molten sodium hydroxide and then treating it with an aqueous etchant for germanium.

2,809,134 Method of Making Photocells—O. T. McIllvaine. Assignee: None. A method of photocell manufacture which comprises the application of a plurality of lines of conducting material onto an insulating base surface and applying a solution of semiconductor over said base to sensitize its surface.

2,809,135 Method of Forming *p-n* Junctions In Semiconductor Material And Apparatus Therefor—F. Koury. Assignee: Sylvania Electric Products Inc. A method of forming a *p-n* junction by providing within the same chamber two melts of material having opposite conductivity types, pulling a crystal from one melt, transferring the crystal to the other melt, and pulling an additional amount of crystal.

2,809,136 Apparatus And Method of Preparing of Silicon And Germanium—G. D. Mortimer. Assignee: Slyvania Electric Products, Inc. A method of preparing thin flat single crystals of germanium and silicon by maintaining proper heating conditions for a melt of said material, using a flat seed crystal in edge contact with the surface of the melt, and raising said seed as the crystal material solidifies.

2,809,239 Transistor Circuits—R. S. Nielsen. Assignee: Sylvania Electric Products, Inc. A small signal reproducing circuit including a transistor, means for providing backconducting bias to the emitter and collector electrodes in relation to the base electrode, a self biasing network in the input circuit, and in said input circuit means for driving the emitter electrode instantaneously forward conducting.

2,809,240 Semiconductor Squelch Circuit—L. A. Freedman. Assignee: Radio Corporation of America. A squelch circuit for a transistorized signal receiver which functions automatically to render the receiver operative when a received carrier wave attains a predetermined amplitude level.

2,809,303 Control Systems For Switching Transistors—H. W. Collins. Assignee: Westinghouse Electric Corporation. The system provides for utilizing a magnetic amplifier energized with a square wave voltage to effect the functioning of a transistor as a switch to control the flow of current to a load.

2,809,304 Transistor Circuits—A. H. Dickinson. Assignee: International Business Machines Corporation. A scaling and trigger circuit which includes a biasing circuit for the base and emitter electrodes of a transistor, said biasing circuit being effective to reduce the output current of the trigger circuit in the OFF state, and to increase the current in the ON state.

2,809,343 Amplifiers—G. F. Pittman, Jr. Assignee: Westinghouse Electric Corporation. A magnetic amplifier that achieves a high speed of response and high power gain by incorporating a transistor in the amplifier circuit in such a way as to cause the voltage induced across the control winding of said amplifier to serve as the supply voltage for the transistor.

October 15, 1957

2,810,024 Efficient And Stabilized Semiconductor Amplifier Circuit—F. O. Stanley. Assignee: Radio Corporation of America. A transistor push-pull amplifier circuit including a transistor driving stage which permits the utilization of a low impedance biasing network for the push-pull power amplifiers.

2,810,073 Stable Transistor Oscillator—R. W. Bradmiller. Assignee: Avco Manufacturing Corporation. A circuit for varying the voltage of a transistor in a compensatory manner and in response to variations of supply voltage or of transistor temperature, said voltage being varied by means of a semiconductor diode resistance network operating in its zener breakdown region.

2,810,080 Transistor Circuits—R. B. Trousdale. Assignee: General Dynamics Corporation. A biasing circuit for transistors, said circuit having a low dynamic impedance which is achieved by providing unidirectional conducting means in the emitter electrode of the transistor.

2,810,081 Electronic Switch for Selectively Blocking or Permitting the Simultaneous Transmission of Signals in Two Channels—G. Elliot. Assignee: General Dynamics Corporation. A transistorized switching circuit capable of switching two channels simultaneously for bilateral transmission in both channels.

2,810,107 Electrical Measuring Instrument—J. W. Sauber. Assignee: Ballantine Laboratories, Inc. A square low voltmeter utilizing a detector of the segmented approximation function generator type employing crystal rectifiers and linear resistors, the segments being cascaded with all rectifiers effectively in series and polarized for conduction in the same direction.

[*To Be Continued*]

CHARACTERISTICS CHART of NEW TRANSISTORS

Announced Between Nov. 1, 1959 and Dec. 31, 1959

This is a partial listing and will be continued in the April issue.

MANUFACTURERS (In Order of Code Letters)

ARA— Advanced Research Associates, Inc.
AEG— Allgemeine Elecktricitats-gesellschaft
AMP— Amperex Electronic Corp.
AEI— Associated Electrical Industries LTD. and Siemens Edison Swan.
BEN— Bendix Aviation Corp.
BOG— Bogue Electric Mfg. Co.
CBS— CBS-Electronics
CRY— Crystalonics, Inc.
CSF— Compagnie Generale
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
EEVB— English Electric Valve Co., Ltd.
ESEB— Edison Swan Electric Co., Ltd.
FSC— Fairchild Semiconductors Corp.
FTHF— French Thomson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GEM— Great Eastern Mfg. Co.
GTC— General Transistor Corp.
HSD— Hoffman Semiconductor Div.
HUG— Hughes Aircraft Co.
HIVB— Hivac Ltd.
IND— Industro Transistor Corp.
LCTF— Labortoire Central de Telecommunications
MIN— Minneapolis-Honeywell Regulator Co.
MOT— Motorola, Inc.
MUL— Mullard Ltd.
NAC— National Semiconductor Corp.
NTLB— Newmarket Transistors Ltd.
NPC— Nucleonics Products Co.
PSI— Pacific Semiconductors, Inc.
PHI— Philco Corp., Landsdale Tube Co.
RAY— Raytheon Co.
RCA— Radio Corp. of America, Semiconductor Div.
RHE— Rheem Semiconductor Corp.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SONY— Sony Corp.
SPE— Sperry Gyroscope Co.
SPR— Sprague Electric Co.
SYL— Sylvania Electric Products Inc.
STCB— Standard Telephone & Cables, Ltd.
TKAD— Suddeutsche Telefon-Apparate-, Kabel und Drahtwerke
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments
TIIB— Texas Instruments Ltd.
TUN— Tung-Sol Electric, Inc.
UST— U. S. Transistor Corp.
WEC— Western Electric Co., Inc.
WEST— Westinghouse Electric Corp.

The following manufacturers have announced that they have begun supplying the indicated previously registered transistors.

AMPEREX: OC44, OC45, 2N281, 2N282
CBS ELECTRONICS: 2N356A, 2N1090, 2N1091
CRYSTALONICS: 2N327A, 2N328A, 2N329A
GENERAL ELECTRIC: 2N388
GENERAL TRANS.: 2N44A,2N331,2N388,2N416,2N417,2N427,2N428, 2N438, 2N464 thru 2N467,2N1118,2N1119
HOFFMAN: 2N696, 2N697
INDUSTRO TRANS.: 2N123,2N359,2N394 thru 2N397,2N582,2N631, 2N696,2N697,2N699,2N1017,2N1252,2N1253,2N1313
NATIONAL SEMI.: 2N327A,2N328A,2N329A,2N1220,2N1222, 2N1228 thru 2N1233
PACIFIC SEMI.: 2N696, 2N697
PHILCO: 2N1294, 2N1295, 2N1296
RAYTHEON: 2N1386, 2N1387, 2N1388, 2N1389, 2N1390
TEXAS INST. ENGLAND: 2N332 thru 2N335,2N337,2N338, 2N389,2N424,2N497,2N498, 3N34, 3N35
TRANSITRON: 2N1247

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics	Gain		MFR. See code at start of charts
				P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	PARAMETER and (condition)	VALUE	
2G104	2,5	PNPMe	Ge	300	250	15		300	$h_{FE}:I_c$- 10ma	40	TIIB
2G220	5	PNPA	Ge		880	40	40		$h_{FE}:I_c$-2.5A	30	TIIB
2G221	5	PNPA	Ge		880	60	60		$h_{FE}:I_c$-2.5A	30	TIIB
2G222	5	PNPA	Ge		880	80	80		$h_{FE}:I_c$-2.5A	30	TIIB
2G223	5	PNPA	Ge		880	40	40		$h_{FE}:I_c$-3.7A	30	TIIB
2G224	5	PNPA	Ge		880	60	60		$h_{FE}:I_c$-3.7A	30	TIIB
2G225	5	PNPA	Ge		880	80	80		$h_{FE}:I_c$-3.7A	30	TIIB
2G226	5	PNPA	Ge		880	40	40		$h_{FE}:I_c$-5.0A	36	TIIB
2G227	5	PNPA	Ge		880	60	60		$h_{FE}:I_c$-5.0A	36	TIIB
2G228	5	PNPA	Ge		880	80	80		$h_{FE}:I_c$-5.0A	36	TIIB
2G229	5	PNPA	Ge		880	40	40		$h_{FE}:I_c$-6.25A	40	TIIB
2G230	5	PNPA	Ge		880	60	60		$h_{FE}:I_c$-6.25A	40	TIIB
2G231	5	PNPA	Ge		880	80	80		$h_{FE}:I_c$-6.25A	40	TIIB
2G240		PNPD	Ge		2660	80	80		$h_{FE}:I_c$-500ma	70	TIIB
2N167A	5	G	Ge	65		30	30	5.0∅	$h_{fe}:I_e$-8.0ma	17-90	GE
2N174	3☐	PNPA	Ge		.80	80	55	10Kc△	$h_{FE}:I_c$-5.0A	40	DEL
2N174A	3☐	PNPA	Ge		1.0	80	40	10Kc△	$h_{FE}:I_c$-5.0A	40	DEL
2N391	3	PNPA	Ge		1.2	50	40	10Kc△	$h_{FE}:I_c$-3.0A	55	DEL
2N414B	5	PNPA	Ge	200		30	16	7.0	$h_{fe}:I_E$-1.0ma	60	IND
2N553	3☐	PNPA	Ge		2.0	80	40	25Kc△	$h_{FE}:I_c$-500ma	55	DEL
2N634A	5	NPNA	Ge	150	400	25	20	5.0∅	$h_{FE}:I_e$- 10ma	40-120	GE
2N635A	5	NPNA	Ge	150	400	25	20	10∅	$h_{FE}:I_e$- 10ma	80-240	GE
2N636A	5	NPNA	Ge	150	400	25	15	15∅	$h_{FE}:I_e$- 10ma	100-300	GE
2N665	3☐	PNPA	Ge		2.0	80	40	20Kc△	$h_{FE}:I_e$-500ma	60	DEL
2N696	3,5☐	NPNMe	Si	600	250	60		150	$h_{FE}:I_c$-150ma	40	FSC

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics: $f_{\alpha b}$ (mc)	Gain: PARAMETER and (condition)	VALUE	MFR. See code at start of charts
2N697	3,5⍁	NPNMe	Si	600	250	60		150	h_{FE}:I_c-150ma	75	FSC
2N698	3,5	NPNMe	Si	600	250	120		150	h_{FE}:I_c-150ma	30	FSC
2N699	3,5⍁	NPNMe	Si	600	250	120		150	h_{FE}:I_c-150ma	65	FSC
2N706	2,5⍁	NPNMe	Si	300	500	25		750	h_{FE}:I_c- 10ma	45	FSC
2N715	2	NPN	Si	500	125	50			h_{FE} at 70Mc	3.0	TII
2N716	2	NPN	Si	500	125	70					TII
2N1011	3⍁	PNPA	Ge		1.2	80	40	7KcΔ	h_{FE}:I_C-3.0A	55	DEL
2N1023	4	PNPD	Ge	120	620	40	40	120	h_{fe}:I_E	60	RCA
2N1066	4	PNPD	Ge	120	620	40	40	120	h_{fe}:I_E	60	RCA
2N1100	3⍁	PNPA	Ge		.80	100	65	10KcΔ	h_{FE}:I_c-5.0A	40	DEL
2N1118A	2	A	Si	150	765	25			h_{fe}:	25	PHI
2N1131	3,5⍁	PNPMe	Si	600	250	40		100	h_{FE}:I_c-150ma	25	FSC
2N1132	3,5⍁	PNPMe	Si	600	250	40		100	h_{FE}:I_c-150ma	40	FSC
2N1157	3	PNPA	Ge		.70	60		.15	h_{FE}:I_C-2.0A	50	MIN
2N1157A	3	PNPA	Ge		.70	80		.15	h_{FE}:I_C-2.0A	50	MIN
2N1160	3⍁	PNPA	Ge		1.2	80	60	10KcΔ	h_{FE}:I_c-5.0A	35	DEL
2N1171	2	A	Ge	150	350	30		15	h_{fe}:I_B-1.0ma	60	RAY
2N1183	3	PNPA	Ge	1000	75	45	20	.50Ø	h_{FE}:I_E-400ma	20min	RCA
2N1183A	3	PNPA	Ge	1000	75	60	30	.50Ø	h_{FE}:I_E-400ma	20min	RCA
2N1183B	3	PNPA	Ge	1000	75	80	40	.50Ø	h_{FE}:I_E-400ma	20min	RCA
2N1184	3	PNPA	Ge	1000	75	45	20	.50Ø	h_{FE}:I_E-400ma	40min	RCA
2N1184A	3	PNPA	Ge	1000	75	60	30	.50Ø	h_{FE}:I_E-400ma	40min	RCA
2N1184B	3	PNPA	Ge	1000	75	80	40	.50Ø	h_{FE}:I_E-400ma	40min	RCA
2N1202	3	PNPA	Ge		2.2	80	60	.20	h_{FE}:I_C-500ma	86	MIN
2N1203	3	PNPA	Ge		2.2	120	70	.20	h_{FE}:I_C-2.0A	37	MIN
2N1204	5	MD	Ge	250	300	20			h_{fe}: 40Mc	10	PHI
2N1224	4⍁	PNPD	Ge	120	620	40	40	30	h_{fe}:I_E-1.5ma	60	RCA
2N1225	4⍁	PNPD	Ge	120	620	40	40	100	h_{fe}:I_E-1.5ma	60	RCA
2N1226	4⍁	PNPD	Ge	120	620	60	60	30	h_{fe}:I_E-1.5ma	60	RCA
2N1252	3,5⍁	NPNMe	Si	600	250	30			h_{FE}:I_c-150ma	35	FSC
2N1253	3,5⍁	NPNMe	Si	600	250	30			h_{FE}:I_c-150ma	45	FSC
2N1261A	3	PNPA	Ge		2.2	80	45	.20	h_{FE}:I_C-2.0A	30	MIN
2N1262A	3	PNPA	Ge		2.2	80	45	.20	h_{FE}:I_C-2.0A	43	MIN
2N1263A	3	PNPA	Ge		2.2	80	45	.20	h_{FE}:I_C-2.0A	64	MIN
2N1358	3⍁	PNPA	Ge		.80	80	55	10KcΔ	h_{FE}:I_c-5.0A	40	DEL
2N1395	4	PNPD	Ge	120	620	40	40	30	h_{fe}:I_E-1.5ma	90	RCA
2N1396	4	PNPD	Ge	120	620	40	40	100	h_{fe}:I_E-1.5ma	90	RCA
2N1397	4	PNPD	Ge	120	620	40	40	120	h_{fe}:I_E-1.5ma	120	RCA
2N1412	3⍁	PNPA	Ge		.80	100	65	10KcΔ	h_{FE}:I_c-5.0A	40	DEL
2N1413	2	A	Ge	200	300	35			h_{fe}:I_e-1.0ma	33	GE
2N1414	2	A	Ge	200	300	35			h_{fe}:I_e-5.0ma	44	GE
2N1415	2	A	Ge	200	300	35			h_{fe}:I_e-1.0ma	64	GE
2N1440	2	PNPA	Si	400	440	50	50	1.0	h_{fe}:	17	NAC
2N1441	2	PNPA	Si	400	440	50	50	1.0	h_{fe}:	26	NAC
2N1442	2	PNPA	Si	400	440	50	50	1.0	h_{fe}:	46	NAC
2N1446	2	PNPA	Ge	200		45	25	2.0	h_{FE}:I_C- 20ma	16	IND
2N1447	2	PNPA	Ge	200		45	25	3.0	h_{FE}:I_C- 20ma	35	IND
2N1448	5	PNPA	Ge	200		45	25	4.0	h_{FE}:I_C- 20ma	50	IND
2N1449	5	PNPA	Ge	200		45	25	5.0	h_{FE}:I_C- 20ma	70	IND
2N1451	2	PNPA	Ge	200		45	20	1.5	h_{FE}:I_C- 20ma	20	IND

NOTATIONS

Under Use

1 - Low power a-f equal to or less than 50 mw
2 - Medium power a-f > 50 mw and equal to or less than 500 mw
3 - Power > 500 mw
4 - r-f/i-f
5 - Switching and Computer
6 - Low Noise
7- Photo
8- Mixer
9- Local Oscillator   ⍁ - Revised Spec.

Under Type

A - Alloyed
D - Diffused or Drift
F - Fused
G - Grown
H - Hook Collector
M - Microalloy
Me - Mesa
O - Other
S - Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
‡ Tetrode

Under f_{ab}

* Maximum Frequency
\# Figure of Merit
Δ $f_{\alpha e}$
Ø Minimum
† f_T = Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_c

Ø - Infinite heat sink

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	DERATING °C/W	V_{cB}	V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	Gain: VALUE	MFR. See code at end of chart
2N1452	2	PNPA	Ge	200		45	20	2.2	h_{FE}:I_C- 20ma	30	IND
2N1468	5	NPNA	Si	250	.54	40	40				RAY
2N1469	2,5	PNPA	Si	150	830		35	2.0Ø	h_{fe}:I_e-1.0ma	36min	SPE
2N1471	5	PNPA	Ge	200		12	12	5.0	h_{FE}:I_C- 20ma	100	IND
2N1472	5	D	Si	100	1250	25	25		h_{fe}: 20Mc	6.3	PHI
2N1473	2,5	NPNA	Ge	167	300	40	20	8.0	h_{FE}:I_e-400ma	50	SYL
2N1478	5	A	Ge	250	300	30	20		h_{FE}:I_c-100ma	35	PHI
2N1479	3	NPNMe	Si	2000	200	60	40	1.5	h_{FE}:I_c-200ma	15min	RCA
2N1480	3	NPNMe	Si	2000	200	100	55	1.5	h_{FE}:I_c-200ma	15min	RCA
2N1481	3	NPNMe	Si	2000	200	60	40	1.5	h_{FE}:I_c-200ma	35min	RCA
2N1482	3	NPNMe	Si	2000	200	100	55	1.5	h_{FE}:I_c-200ma	35min	RCA
2N1483	3	NPNMe	Si	7500	100	60	40	1.25	h_{FE}:I_c-750ma	15min	RCA
2N1484	3	NPNMe	Si	7500	100	100	55	1.25	h_{FE}:I_c-750ma	15min	RCA
2N1485	3	NPNMe	Si	7500	100	60	40	1.25	h_{FE}:I_c-750ma	35min	RCA
2N1486	3	NPNMe	Si	7500	100	100	55	1.25	h_{FE}:I_c-750ma	35min	RCA
2N1487	3	NPNMe	Si	30W	2.5	60	40	1.0	h_{FE}:I_c-1.5A	10min	RCA
2N1488	3	NPNMe	Si	30W	2.5	100	55	1.0	h_{FE}:I_c-1.5A	10min	RCA
2N1489	3	NPNMe	Si	30W	2.5	60	40	1.0	h_{FE}:I_c-1.5A	25min	RCA
2N1490	3	NPNMe	Si	30W	2.5	100	55	1.0	h_{FE}:I_c-1.5A	25min	RCA
2N1500	5	MD	Ge	75	530	15	12		h_{fe}: 20Mc	4.5	PHI
2N1505	3	DM	Si	3000	50	50	40		PG at 70Mc	10db	PSI
2N1506	3	DM	Si	3000	50	60	40		PG at 70Mc	12db	PSI
2N1585	2	PNPMe	Ge	300	250	25		400	h_{FE}:I_C- 10ma	20	TII
2S012	5	NPND	Si		3300		60		h_{FE}:I_c-1.0A	10min	TIIB
2S012A	5	NPND	Si		2000		70	.30	h_{FE}:I_c-1.5A	20min	TIIB
2S013A	5	NPND	Si		2000		60	.30	h_{FE}:I_c-1.5A	15min	TIIB
2S019	3	NPND	Si	4000		60	60		h_{fe}:I_c- 30ma	60	TIIB
2S020	3	NPND	Si	4000		100	100		h_{fe}:I_c- 30ma	60	TIIB
2S021	2	PNPA	Si	300		80	60		h_{FE}:I_c- 10ma	25	TIIB
2S022	2	PNPA	Si	300		40	25	.30Ø	h_{FE}:I_c- 10ma	33	TIIB
2S023	2	PNPA	Si	300		40	25	.80Ø	h_{FE}:I_c- 10ma	6.0	TIIB
2S101	2,5	NPNMe	Si	300		25	25	150†	h_{fe}:I_c- 10ma	12	TIIB
3S001	2	NPND§	Si	125		30					TIIB
3S003	2	NPND§	Si	125		30					TIIB
C101	2,5	PNPY	Si	250	540	30	20	.40	h_{FE}:I_c-.10ma	9.0	CRY
C102	2,5	PNPY	Si	250	540	30	15	.80	h_{FE}:I_c-.10ma	13	CRY
C103	2,5	PNPY	Si	250	540	30	10	1.2	h_{FE}:I_c-.10ma	19	CRY
C112	2	PNPA	Si	250	540	25	25		h_{fe}:I_e-.20ma	18	CRY
C201	2,5	PNPY	Si	250	540	40	40	.40			CRY
C202	2,5	PNPY	Si	250	540	25	12	.80			CRY
C301	2,5	PNPY	Si	250	540	70	70	.40			CRY
C302	2,5	PNPY	Si	250	540	12	8.0	.80			CRY
C401	2,5	PNPY	Si	250	540	40	40				CRY
C402	2,5	PNPY	Si	250	540	15	10	.80			CRY
CK942	2	A	Si	250	.54	50	20	.10	h_{fe}:6.0V,1.0ma	9.0	RAY
CTP1728	5	PNPA	Ge	30W	2.5	40	38		h_{FE}:I_c-500ma	50	CLE

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Under f_{ab}

* Maximum Frequency
\# Figure of Merit
Δ $f_{\alpha e}$
Ø Minimum
† f_T = Gain Bandwidth Product h_{fe} x f_{hfe}

Under P_c

Ø - Infinite heat sink

CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

ANNOUNCED BETWEEN OCT. 1, 1959 and NOV. 30, 1959 ONLY. This is a partial listing continued from the Feb./1960 issue.

MANUFACTURERS

AEG— Allgemeine Elekticitats-Gesellschaft
AEI— Associated Electrical Industries, Ltd.
AMP— Amperex Electronic Corp.
AUD— Audio Devices, Inc.
BEN— Bendix Aviation Corp.
BER— Berkshire Labs
BOG— Bogue Electric Mfg. Co.
BOM— Bomac Labs
BRA— Bradley Labs
CBS— CBS Electronics
CDC— Continental Device Corp.
COL— Columbus Electronics Corp.
CTP— Clevite Transistor Products, Inc.
CSF— Compagnie Generale de T.S.F.
DAL— Dallons Semiconductor
DEL— Delco Radio
EEVB— English Electric Valve Co., Ltd.
ERI— Erie Resistor Corp.
FAN— Fansteel Metallurgical Corp.
FERB— Ferranti Ltd.
GAH— Gahagan, Inc.
GECB— General Electric Co., Ltd.
GE— General Electric Company, Semiconductor Div.
GIC— General Instrument Corp.
GTC— General Transistor Corp.
HAFO— Institutet for Halvedarforskning
HSD— Hoffman Semiconductor Division
HUG— Hughes Products Division
INRC— International Rectifier Corp.
IRC— International Resistance Co.
ITT— International Tel. & Tel. Corp.
KEM— Kemtron Electron Products, Inc.
LCTF— Laboratoire Central de Telecommunications
MAL— P. R. Mallory & Co., Inc.
MIC— Microwave Associates, Inc.
MOT— Motorola, Inc.
MUL— Mullard, Ltd.
NAE— North American Electronics
NPC— Nucleonic Products Co., Inc.
OHM— Ohmite Manufacturing Co.
PHI— Philco Corp. Lansdale Tube Company
PSI— Pacific Semiconductors, Inc.
QSC— Qutronic Semiconductor Corp.
RAY— Raytheon Company
RCA— Radio Corporation of America, Semiconductor Div.
RHE— Rheem Semiconductor Corp.
SAR— Sarkes Tarzian, Inc., Rectifier Division
SCN— Semicon, Inc.
SEM— Semi-Elements Inc.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SSD— Sperry Semiconductor Division
SSP— Solid State Products, Inc.
STC— Shockley Transistor Corp.
STCB— Standard Telephone & Cables, Ltd.
SYL— Sylvania Electric Products, Inc.
SYN— Syntron Co.
TEX— Texas Research Assoc.
TFKG— Telefunken, Ltd.
TI— Texas Instruments, Inc.
TKD— Tekade, Nurnberg, Germany
TOK— Tokyo Tsushin Kogyo, Ltd.
TRA— Transitron Electronic Corp.
TUN— Tung-Sol Electric, Inc.
TSC— Trans-Sil Corp.
UCI— United Components
USD— United States Dynamics Corp.
USS— U. S. Semiconductor Products, Inc.
VIC— Vickers Inc.
WEC— Western Electric Co.
WEST— Westinghouse Electric Corp.

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z (ohms)	@ I_z (ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. (See code at start of chart)
1/4M6.8Z	5.4	8.2	9.2	7.0	9.2	250	.040	MOT
1/4M7.5Z	6.0	9.0	8.3	8.0	8.3	250	.045	MOT
1/4M8.2Z	6.6	9.8	7.6	9.0	7.6	250	.048	MOT
1/4M9.1Z	7.3	10.9	6.9	10	6.9	250	.051	MOT
1/4M10Z	8.0	12	6.3	11	6.3	250	.055	MOT
1/4M11Z	8.8	13.2	5.7	13	5.7	250	.060	MOT
1/4M12Z	9.6	14.4	5.2	15	5.2	250	.065	MOT
1/4M13Z	10.4	15.6	4.8	18	4.8	250	.065	MOT
1/4M14Z	11.2	16.8	4.5	20	4.5	250	.070	MOT
1/4M15Z	12	18	4.2	22	4.2	250	.070	MOT
1/4M16Z	12.8	19.2	3.9	24	3.9	250	.070	MOT
1/4M17Z	13.6	20.4	3.7	26	3.7	250	.075	MOT
1/4M18Z	14.4	21.6	3.5	28	3.5	250	.075	MOT
1/4M19Z	15.2	22.8	3.3	30	3.3	250	.075	MOT
1/4M20Z	16	24	3.1	33	3.1	250	.075	MOT
1/4M22Z	17.6	26.4	2.8	40	2.8	250	.080	MOT
1/4M24Z	19.2	28.8	2.6	46	2.6	250	.080	MOT
1/4M25Z	20	30	2.5	50	2.5	250	.080	MOT
1/4M27Z	21.6	32.4	2.3	58	2.3	250	.085	MOT
1/4M30Z	24	36	2.1	70	2.1	250	.085	MOT
1/4M33Z	26.4	39.6	1.9	85	1.9	250	.085	MOT
1/4M36Z	28.8	43.2	1.7	100	1.7	250	.085	MOT
1/4M39Z	31.2	46.8	1.6	120	1.6	250	.090	MOT
1/4M43Z	34.4	51.6	1.5	140	1.5	250	.090	MOT
1/4M45Z	36	54	1.4	150	1.4	250	.090	MOT
1/4M47Z	37.6	56.4	1.3	160	1.3	250	.090	MOT
1/4M50Z	40	60	1.2	180	1.2	250	.090	MOT
1/4M52Z	41.6	62.4	1.2	200	1.2	250	.090	MOT
1/4M56Z	44.8	67.2	1.1	230	1.1	250	.090	MOT
1/4M62Z	49.6	74.4	1.0	290	1.0	250	.090	MOT
1/4M68Z	54.4	81.6	.92	350	.92	250	.090	MOT
1/4M75Z	60	90	.83	450	.83	250	.090	MOT
1/4M82Z	65.6	98.4	.76	550	.76	250	.090	MOT
1/4M91Z	72.8	109	.69	700	.69	250	.090	MOT
1/4M100Z	80	120	.63	900	.63	250	.090	MOT
1/4M105Z	84	126	.60	1000	.60	250	.095	MOT
1/4M110Z	88	132	.57	1200	.57	250	.095	MOT
1/4M120Z	96	144	.52	1500	.52	250	.095	MOT
1/4M130Z	104	156	.48	1900	.48	250	.095	MOT
1/4M140Z	112	168	.45	2200	.45	250	.095	MOT

TYPE NO.	Zener or Avalanche Voltage Range MIN. Eb1 (volts)	MAX. Eb2 (volts)	@ Iz (ma)	Dynamic Impedance Z @ Iz (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. {See code at start of chart}
1/4M150Z	120	180	.42	2500	.42	250	.095	MOT
1/4M175Z	140	210	.36	3300	.36	250	.095	MOT
1/4M200Z	160	240	.31	4300	.31	250	.100	MOT
1N1507A	3.7	4.1	35			750	.04	INRC
1N1508A	4.5	4.9	30			750	0	INRC
1N1509A	5.3	5.9	26			750	.03	INRC
1N1510A	6.5	7.1	22			750	.05	INRC
1N1511A	7.8	8.6	18			750	.06	INRC
1N1512A	9.5	10.5	15			750	.07	INRC
1N1513A	11.4	12.6	12			750	.075	INRC
1N1514A	14.2	15.8	10			750	.08	INRC
1N1515A	17.1	18.9	8.0			750	.085	INRC
1N1516A	20.9	23.1	6.0			750	.09	INRC
1N1517A	25.6	28.4	5.0			750	.095	INRC
1N1518A	3.7	4.1	50			1000	.04	INRC
1N1519A	4.5	4.9	40			1000	0	INRC
1N1520A	5.3	5.9	35			1000	.03	INRC
1N1521A	6.5	7.1	30			1000	.05	INRC
1N1522A	7.8	8.6	25			1000	.06	INRC
1N1523A	9.5	10.5	20			1000	.07	INRC
1N1524A	11.4	12.6	15			1000	.075	INRC
1N1525A	14.2	15.8	13			1000	.08	INRC
1N1526A	17.1	18.9	10			1000	.085	INRC
1N1527A	20.9	23.1	9.0			1000	.09	INRC
1N1528A	25.6	28.4	7.0			1000	.095	INRC
1N1588A	3.7	4.1	150			3500	.04	INRC
1N1589A	4.5	4.9	125			3500	0	INRC
1N1590A	5.3	5.9	110			3500	.03	INRC
1N1591A	6.5	7.1	100			3500	.05	INRC
1N1592A	7.8	8.6	80			3500	.06	INRC
1N1593A	9.5	10.5	70			3500	.07	INRC
1N1594A	11.4	12.6	50			3500	.075	INRC
1N1595A	14.2	15.8	40			3500	.08	INRC
1N1596A	17.1	18.9	35			3500	.085	INRC
1N1597A	20.9	23.1	30			3500	.09	INRC
1N1598A	25.6	28.4	25			3500	.095	INRC
1N1599A	3.7	4.1	500			10W	.04	INRC
1N1600A	4.5	4.9	400			10W	0	INRC
1N1601A	5.3	5.9	350			10W	.03	INRC
1N1602A	6.5	7.1	300			10W	.05	INRC
1N1603A	7.8	8.6	250			10W	.06	INRC
1N1604A	9.5	10.5	200			10W	.07	INRC
1N1605A	11.4	12.6	170			10W	.075	INRC
1N1606A	14.2	15.8	140			10W	.08	INRC
1N1607A	17.1	18.9	110			10W	.085	INRC
1N1608A	20.9	23.1	90			10W	.09	INRC
1N1609A	25.6	28.4	70			10W	.095	INRC
1Z4.3T5	4.1	4.5	50			1000	.04	INRC
1Z4.7T20	3.8	5.6	40			1000	0	INRC
1Z5.1T5	4.8	5.4	40			1000	0	INRC
1Z6.2T5	5.9	6.5	35			1000	.03	INRC
1Z6.8T20	5.4	8.2	30			1000	.05	INRC
1Z7.5T5	7.1	7.9	30			1000	.05	INRC
1Z9.1T5	8.6	9.6	25			1000	.06	INRC
1Z10T20	8.0	12	20			1000	.07	INRC
1Z11T5	10.4	11.6	20			1000	.07	INRC
1Z13T5	12.3	13.7	15			1000	.075	INRC
1Z15T20	12	18	13			1000	.08	INRC
1Z16T5	15.2	16.8	13			1000	.08	INRC
1Z20T5	19	21	10			1000	.085	INRC
1Z22T20	17.6	24.4	9.0			1000	.09	INRC
1Z24T5	22.8	25.2	9.0			1000	.09	INRC
1Z30T5	28.5	31.5	7.0			1000	.095	INRC
3Z4.3T5	4.1	4.5	150			3500	.04	INRC
3Z4.7T20	3.8	5.6	125			3500	0	INRC
3Z5.1T5	4.8	5.4	125			3500	0	INRC
3Z6.2T5	5.9	6.5	110			3500	.03	INRC
3Z6.8T20	5.4	8.2	100			3500	.05	INRC
3Z7.5T5	7.1	7.9	100			3500	.05	INRC
3Z9.1T5	8.6	9.6	80			3500	.06	INRC
3Z10T20	8.0	12	70			3500	.07	INRC
3Z11T5	10.4	11.6	70			3500	.07	INRC
3Z13T5	12.3	13.7	50			3500	.075	INRC
3Z15T20	12	18	40			3500	.08	INRC
3Z16T5	15.2	16.8	40			3500	.08	INRC
3Z20T5	19	21	35			3500	.085	INRC
3Z22T20	17.6	24.4	30			3500	.09	INRC
3Z24T5	22.8	25.2	30			3500	.09	INRC
3Z30T5	28.5	31.5	25			3500	.095	INRC
10Z4.3T5	4.1	4.5	500			10W	.04	INRC

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. (See code at start of chart)
10Z4.7T20	3.8	5.6	400			10W	0	INRC
10Z5.1T5	4.8	5.4	400			10W	0	INRC
10Z6.2T5	5.9	6.5	350			10W	.03	INRC
10Z6.8T20	5.4	8.2	300			10W	.05	INRC
10Z7.5T5	7.1	7.9	300			10W	.05	INRC
10Z9.1T5	8.6	9.6	250			10W	.06	INRC
10Z10T20	8.0	12	200			10W	.07	INRC
10Z11T5	10.4	11.6	200			10W	.07	INRC
10Z13T5	12.3	13.7	170			10W	.075	INRC
10Z15T20	12	18	140			10W	.08	INRC
10Z16T5	15.2	16.8	140			10W	.08	INRC
10Z20T5	19	21	110			10W	.085	INRC
10Z22T20	17.6	24.4	90			10W	.09	INRC
10Z24T5	22.8	25.2	90			10W	.09	INRC
10Z30T5	28.5	31.5	70			10W	.095	INRC
MZ4.3T5	4.1	4.5	35			750	.04	INRC
MZ4.7T20	3.8	5.6	30			750	0	INRC
MZ5.1T5	4.8	5.4	30			750	0	INRC
MZ6.2T5	5.9	6.5	26			750	.03	INRC
MZ6.8T20	5.4	8.2	22			750	.05	INRC
MZ7.5T5	7.1	7.9	22			750	.05	INRC
MZ9.1T5	8.6	9.6	18			750	.06	INRC
MZ10T20	8.0	12	15			750	.07	INRC
MZ11T5	10.4	11.6	15			750	.07	INRC
MZ13T5	12.3	13.7	12			750	.075	INRC
MZ15T20	12	18	10			750	.08	INRC
MZ16T5	15.2	16.8	10			750	.08	INRC
MZ20T5	19	21	8.0			750	.085	INRC
MZ22T20	17.6	24.4	6.0			750	.09	INRC
MZ24T5	22.8	25.2	6.0			750	.09	INRC
MZ30T5	28.5	31.5	5.0			750	.095	INRC
OAZ200	4.4	5.0	1.0	350	1.0	250	2.0	AMP
OAZ201	4.8	5.4	1.0	340	1.0	250	1.8	AMP
OAZ202	5.3	6.0	1.0	260	1.0	250	1.5	AMP
OAZ203	5.8	6.6	1.0	160	1.0	250	1.0	AMP
OAZ204	6.4	7.2	1.0	40	1.0	250	3.0	AMP
OAZ205	7.1	7.9	1.0	10	1.0	250	4.0	AMP
OAZ206	7.7	8.7	1.0	8.0	1.0	250	6.5	AMP
OAZ207	8.6	9.6	1.0	8.0	1.0	250	6.5	AMP
SX761	30	45	1.0	100	5.0	300	.09	GECE

CHARACTERISTICS CHART of SWITCHING DIODES

TYPE NO.	MAT	PIV (volts)	MAX. CONT. REV. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f (mA)	@ E_f (volts)	Reverse Impedance @ 25°C Z (K ohms)	VOLTAGE RANGE E_{b1} to E_{b2} (volts)	Recovery Characteristics TEST CONDITIONS Fwd. I_f (ma)	Rev. E_b (volts)	$Z_{rec.}$ (K ohms)	@ time (t) (usec)	MFR. (See code at start of charts)
1N777	Ge	70	60	100	1.0			30	40	50	.50	GTC
1N914	Si	75						10	6.0		4.0m	TII
1N916	Si	75						10	6.0		4.0m	TII
1N920	Si	40	36	500	1.0	150M	30	500	50	10	.30	SSD
1N921	Si	80	70	500	1.0	300M	60	500	50	10	.30	SSD
1N922	Si	120	100	500	1.0	450M	90	500	50	10	.30	SSD
1N923	Si	50	130	500	1.0	600M	120	500	50	10	.30	SSD
1N925	Si	40		5.0	1.0	10M	10	5.0	10	20	.15	PSI
1N926	Si	40		5.0	1.0	100M	10	5.0	10	20	.15	PSI
1N927	Si	65		10	1.0	100M	10	5.0	10	20	.15	PSI
1N928	Si	120		10	1.0	100M	10	5.0	10	20	.15	PSI
1N934	Si	70		20	1.0						2.0	UCI
D1820	Ge		20	10	1.3			2.0u			2.5m	SYL
PD101	Si	50		5.0	1.0	10M	10			100	1.0	PSI
PD102	Si	50		20	1.0	20M	10			100	.30	PSI
PD103	Si	50		100	1.0	20M	10			100	.30	PSI
PD104	Si	100		5.0	1.0	20M	10			100	.30	PSI
PD105	Si	100		20	1.0	20M	10			100	.30	PSI
PD106	Si	100		50	1.0	20M	10			100	.30	PSI
PD107	Si	100		100	1.0	20M	10			100	.30	PSI
PD108	Si	200		10	1.0	20M	10 100			200	.30	PSI
PD109	Si	200		10	1.0	400M	10			200	.30	PSI
RD2121	Si	60		50	1.0	100M	50	5.0	40	200	.20	RHE
RD2122	Si	120		50	1.0	200M	100	5.0	40	200	.20	RHE
RD2123	Si	175		50	1.0	300M	150	5.0	40	200	.20	RHE
RD2124	Si	225		50	1.0	400M	200	5.0	40	200	.20	RHE

Market News . . .

Sales

R C A Semiconductor and Materials Division has established a Southwest District Sales Office in Dallas which will cover sales in Texas, Oklahoma, New Mexico, Arkansas and Louisiana. This office will handle the Division's products including transistors, silicon rectifiers, and ferrites as well as developmental samples of micromodules and the newly announced germanium tunnel diode.

The United States Department of Commerce in a recent report points out that the factory output of semiconducor devices, transistors, diodes, and rectifiers increased 75% above that of 1958. The increase in the last few years has been as shown in the following table

Year	Millions of dollars
1952	20
1953	25
1954	25
1955	40
1956	90
1957	150
1958	210
1959	370 (preliminary figure)

The Electronics Division, Business and Defense Services Administration has reported an increase in the export of semiconductors. There was approximately a 12% increase for the first nine months of this year over last year's figures

Year	Jan-Sept
1958	$5,772,000
1959	$6,461,000

The Bureau of Mines in a recently issued report stated that 125 million germanium transistors, diodes and rectifiers were produced in 1959. This is more than double the output for 1958. The electronic industry consumed nearly all of the estimated 45,000 lbs of domestic produced germanium.

The Bureau said that two major developments in germanium technology will have an important bearing on its future. These were the announcements by Westinghouse Electric Corp., of the successful growth of thin, uniform and flat ribbons of germanium in dentritic single crystals and by General Electric Co., that they now have available tunnel diodes in quantities.

The Bureau also reported that shipments of selenium had grown from 737,000 lbs. in 1958 to about one million lbs. or a gain of 36% in 1959. About one half of this was consumed in the manufacture of dry plate rectifiers.

Hoffman Electronics Corp., Semiconductor Division has appointed Radio Electronic Supply Co., Grand Rapids, Mich., and its subsidiary Rissi Electronic Supply Co., Detroit as distributors.

Sylvania Electric Products Semiconductor Division has opened a sales office in Wilmington, Mass., to meet the increased demand for transistors and diodes in the New England area.

Japan Electronic Industries Association has reported that Japanese semiconductor devices totaled 14 million units in October 1959, compared with 13 million units the month before. The association reports that the output of semiconductors is increasing about one million units a month.

Prices

The General Electric Company has reduced prices from twenty to forty percent on its production models of silicon controlled rectifiers. The new prices range from $18.50 to $95.00 each on the eight models in the 16 ampere line; from $14.00 to $71.00 each on the eight types comprising the 10 ampere line; and from $24.00 to $114.00 each on the seven devices in the inverter series. Prices on military low current rectifiers have also been reduced by 28% to 61%.

Sperry Semiconductor Division of South Norwalk, Conn., has made price reductions of up to 37% in the IN690-IN693 series of high current, fast switching silicon diodes. Prices of the IN690 in 100-999 quantities has been reduced from $4.45 to $3.05. Sperry has also announced that they have available the IN920-IN923 series, featuring 0.3 micro second switching of ½ ampere pulses.

Silicon Transistor Corp., Carle Place, N.Y., has announced price reductions of about 35% on two high power-low saturation resistance silicon transistors. Prices of the 2N1069 are $60.40 for quantities under 100 and $40.25 for 100 and over. The 2N1070 is now priced at $71.40 for quantities under 100 and $47.60 for 100 and over.

Hoffman Electronics Corp., has put into production two new silicon mesa transistors 2N696 and 2N697. The price of each is $28.50 in quantities up to 99, and $19.00 each in quantities from 100 to 999.

Raytheon Co., Semiconductor Division has introduced the CK942 *p-n-p* fusion-alloy silicon transistor. In quantities up to 99 they will sell for $5.25 each, and at $3.50 each in quantities from 100 to 999.

Sprague Electric Co., North Adams, Mass. has announced a price decrease from 5 to 10% on their metal-clad solid-electrolyte tantalum capacitors. Their hermetically-sealed solid-tantalum capacitors have wide applications in transistorized electronic equipment.

Standard Telephones and Cables, Ltd., London plans to market tunnel diodes in the United States through its parent firm, International Telephone and Telegraph Corp. Sample prices will be high but production models will be substantially less than $75.00 each in the United States.

The Bureau of Mines has reported semiconductor material prices as follows per lb.

Germanium refined	$202.27-220.45
Silicon transistor grade	$130.00-355.00
Selenium, high purity	$9.50

Fairchild Semiconductor Corporation has reduced prices across the board on its line of high performance diffused silicon transistors. Typical of the revised prices are the 2N696 and 2N697 all purpose NPN units which were reduced from $28.50 to $22.70 in 1-99 quantities. Another item affected by the February 1 adjustment is the 2N1131. Prices are down from $37.50 to $28.80 in 1-99 quantities. These were first introduced to industry less than one year ago at a price of $75.00.

Suppliers

United States Transistor Corp., Syosset, N.Y., is now producing a complete line of germanium alloy junction and silicon transistors for use in communications devices and military components. Production for the present is set at $50,000 worth a month. When peak production is reached its capacity will be 35,000 transistors per day on a 16 hour shift.

R.C.A. Semiconductor Division, Somerville, N.J., has announced a new family of ten industrial "drift field" germanium p-n-p type transistors. These are said to operate with exceptional stability up to 50 megacycles and above in RF amplifier service and 125 megacycles and above in oscillator service.

Sperry Semiconductor Division of Sperry Rand Corp., has widened their line of diodes and transistors by adding 44 new silicon devices. Included in this are 12 new general purpose diodes and 18 new computor diodes.

Financial

National Semiconductor of Danbury, Conn., has recently placed $500,000 in convertible notes for expansion. These funds will be added to the $650,000 raised six months ago at the founding of the company.

Transitron Electronics Corp., has made application to the New York Stock Exchange for original listing of its 7,877,500 outstanding shares of common stock, at $1.00 par value.

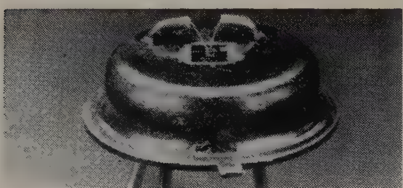
(Continued on page 83)

New Products

Silicon Mesa Transistor Line

Hoffman Electronics Corporation recently announced two newly-developed silicon mesa transistors. These diffused junction, drift field mesa transistors, (JEDEC No.'s 2N696 and 2N697) are designed for use as high speed switching units operating at medium power levels and as very high frequency amplifiers. The only difference between the two is a higher DC pulse current gain in the 2N697. This measures a minimum of 40 and a maximum of 120 compared to a minimum of 20 and a maximum of 60 in the 2N696.

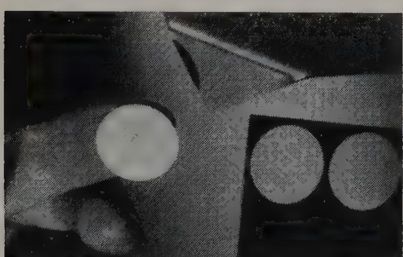
Circle 111 on Reader Service Card



Clad-Molybdenum Sheet

The development of nickel-clad and copper-clad molybdenum sheet metal with improved soldering and durability characteristics was announced by General Electric Company's Lamp Metals and Components Department. Clad molybdenum is expected to be used extensively in semiconductor products, such as silicon power rectifiers. Available in thicknesses from 0.010 through 0.080" and in widths up to 4". Clad moly sheet can be supplied with cladding on one or both sides. Standard thickness of the cladding (which is included as part of the specified thickness of the sheet) is 0.0005 to 0.001".

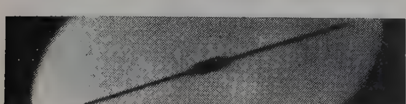
Circle 112 on Reader Service Card



Silicon Computer Diodes

Fast switching silicon computer diodes with U. S. Army Signal Corps Single Service specification approval are now available from Rheem Semiconductor Corp. These Signal Corps types feature recovery times down to 0.3 microseconds with reverse voltages ranging up to 200 volts. They are listed under type numbers 1N643 (MIL-E-1/1171), 1N658 (MIL-E-1/1160), 1N662 (MIL-E-1/1139) and 1N663 (MIL-E-1/1140). They are sealed in the standard glass package.

Circle 135 on Reader Service Card



NPN Transistor

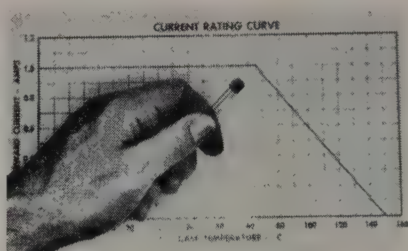
2N717 is a high speed general purpose silicon transistor now available from Fairchild Semiconductor Corporation. Saturated switching times are tenths of a microsecond at one half ampere. Typical gain-bandwidth product is 100 mc. In low level amplifier service 2N717 provides 15 db neutralized gain at 30 mc. Current gain is essentially flat over a two decade range of current. JEDEC TO-18 package permits 1.5 watts dissipation at room temperature.

Circle 162 on Reader Service Card

Silicon Controlled Rectifiers

Five new P-N-P-N diffused silicon controlled rectifiers, the TI-110 series, were announced by Texas Instruments. TI-110 through TI-114 provide output currents of 1 ampere at 65°C case temperature and average rectified forward currents of 300 ma at 125°C case temperature with peak inverse voltages and minimum forward breakover voltages from 50 to 400 volts. The maximum gate current required to turn on the device is 20 ma with maximum holding current of 25 ma and maximum leakage current at PIV (or forward breakover voltage) of 1 ma.

Circle 114 on Reader Service Card



Semiconductor Grade Phosphorus

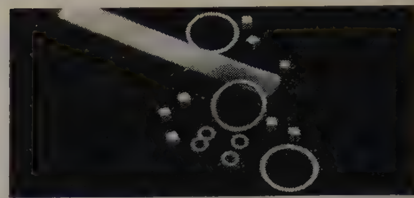
A new, ultrapure grade of elemental phosphorus of particular interest in semiconductor manufacture has been developed by the Research Department, Chemical Division, of The American Agricultural Chemical Company. Electron mobility tests on gallium phosphide produced from this phosphorus indicate a purity of 99.9999% or better. Presently available in quartz ampules of 30 grams net weight. In addition to its major application as an intermetallic in semiconductors for high-temperature electronic systems, phosphorus of this ultrapure quality finds use in electroluminescent coatings.

Circle 128 on Reader Service Card

Miniature Gold Preforms

Miniature gold preforms, used in the manufacture of semiconductor devices such as diodes and transistors, have been made available by Alpha Metals. The tiny gold preforms are used as a high-temperature solder for attaching the wafer to the base tab or for making electrical contact between leads and studs. The highly refined gold approaches the 99.999% purity requirements of semiconductor junctions and closures. Exemplifying the dimensions involved are washers as small as .020" i.d. and .030" o.d.

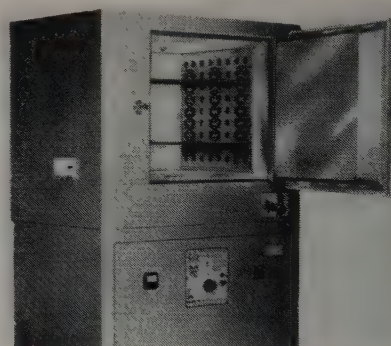
Circle 140 on Reader Service Card



Oven Control System

A recent invention by Blue M Electric Co., replacing conventional on-off type, resistance thermometers and multiple switch-type controls, is their new Power-O-Matic 60 Saturable Power Reactor Control with a fail-safe device called Range-Lock. Power-O-Matic 60 series of Mechanical Convection Ovens with horizontal airflow, utilizes a saturable power reactor, with a Hypersil core, in combination with a stainless steel hydraulic bellows and variable gap inductor coil which automatically varies the voltage (wattage) to the resistive load. This control system is completely stepless, switchless, and infinitely proportional. Temperature is constant, straight-line and repetitive throughout the entire oven range.

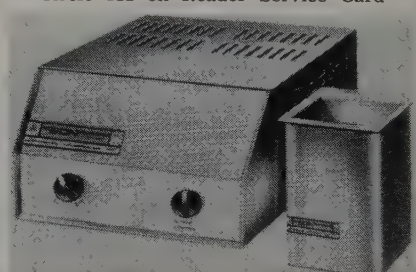
Circle 110 on Reader Service Card



Ultrasonic Cleaner

An economical ultrasonic cleaner, the diSONtegrator System Forty, has been introduced by Ultrasonic Industries, Inc. A full half-gallon capacity model, it will now enable any company or small establishment to take full advantage of ultrasonic cleaning. It includes the Model G-40C1, a powerful 40 watt generator with an output of 90,000 cycles per second. The cabinet measures 10"L. x 8"W. x 5¾"H, and features only one control knob.

Circle 122 on Reader Service Card



Dust Hood

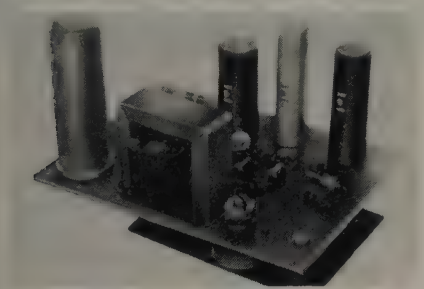
Critical laboratory, manufacturing, and inspection operations can be performed under dust-free conditions in a new dust hood manufactured by Air-Shields Incorporated. "Microvoid" allows full visibility and unimpeded movement of arms and hands. Working area of the unit measures 34″ long by 24″ deep by 19¼″ high. It is rigidly constructed of optically-clear, quarter-inch "Plexiglas" with all edges fused and flame-polished to eliminate shadows, rough surfaces, and leakage. Weight is only 35 pounds.

Circle 124 on Reader Service Card

Power Supply Line

A family of compact, transistorized regulated power supplies designed to meet a wide range of requirements in original equipment, ground support systems, computers and laboratory has been introduced by Transistor Specialties, Inc. They are available in a range of models providing output ratings from 6 volts to 50 volts and currents up to 1 ampere for low voltage applications and up to 2000 volts at 1 ma. for high voltage service. All models utilize printed circuit construction.

Circle 147 on Reader Service Card



Low Resistance Thermistor

A new low resistance thermistor for use in liquid nitrogen temperature ranges has just been added to the Victory Engineering Corp. line. The VECO 05A8 bead type thermistor has a resistance of 100,000 ohms at −195.8° C. and is hermetically sealed in a glass probe. This easier-to-read resistance value exhibits exceptionally high reliability, high sensitivity and fast time response.

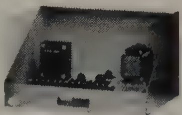
Circle 156 on Reader Service Card

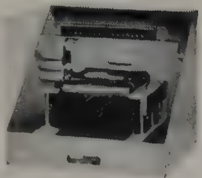
Molded Transistor Transformers

Ultra Miniature Molded Transistor Transformers have been announced by Microtan Company. The size of these epoxy molded units is ½″ diameter x ½″ high. Weight is 4 grams. Electrical ratings provide primary impedances of 400 to 100,000 ohms and secondary impedances of 11 to 2500 ohms. On special order, center taps and 130°C construction are available. Wattage ranges from 2.5 milliwatts to 8 milliwatts.

Circle 151 on Reader Service Card

(Continued on page 84)





Market News

(from page 78)

General Instrument Corp., has reported that for the nine month period, ending Nov. 30, 1959, it earned a net profit of $1,378,233 equal to 90 cents per share. This was 43% higher than the 1958 nine month figure of $960,717 or 70 cents per share. Sales increased 20% to $41,277,875 from $34,161,392. Their backlog at the end of this period was $33,238,000.

Expansions

Knapic Electro-Physics, Inc., of Palo Alto, a major supplier of grown silicon and germanium monocrystals has just completed its new plant facilities. The new addition, doubling the existing floor space will be used to expand the company's research and development program.

Glass-Tite Industries, manufacturer of hermetic seals and terminals for semiconductor relays, crystal bases and custom applications has formed a new subsidiary, Escon Inc., which will specialize in connectors with special emphasis on custom applications.

Transitron of Wakefield, Mass., has purchased the former Maverick Mills plant in Boston containing some 40,000 square feet of space. This acquisition more than doubles the amount of space the firm has available in their Wakefield and Melrose plants. The firm plans to hire between 2000 to 3500 technical and non-technical persons to staff their Boston plant.

Erie Resistor Corporation of Erie, Pa., has announced the opening of Electron Research, Inc., a wholly owned subsidiary, for the purpose of manufacturing semiconductor components and devices. Present production consists of a line of 37 standard and 20 special glass packaged germanium diodes. A line of miniature diodes will be introduced shortly.

General Electric Co., plans to spend about $1 million for new facilities to increase production of transistors in 1960 in its semiconductor plant in Buffalo. This addition is expected to result in the hiring of additional personnel.

Lark Corp., Dallas, Texas has moved into the electronics field by purchasing the Santa Ana, Cal. Silicon Rectifier Division from Audio Devices Inc.

Cornell-Dubilier Electric Corp., has purchased the United States Dynamics Corp., Boston, Mass. United States Dynamics is mainly a research organization but it does manufacture 12 ampere silicon diodes.

General Telephone and Electronics Corporation has formed the General Telephone and Electronics Laboratories Inc., as a wholly owned subsidiary. The new company will be engaged in research activities in semiconductors, communications and other electronics fields.

Contracts

U.S. Transistor Corp., Syosset, N.Y., has received its first defense contract from Wright Field for $22,000 for germanium *p-n-p* alloy junction transistors.

Texas Instruments Inc., was awarded a $4.5 million contract by the newly formed Bureau of Naval Weapons for the production

(Continued on page 95)

Sensistor Silicon Resistors

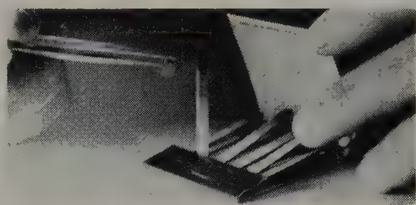
Sensistor silicon resistors with values extending from 68 ohms to 1.8K ±10% tolerance as standard items were announced recently by Texas Instruments. Special values from 62 ohms to 2K with tolerances of ±5% and ±10% are also available. Extending the ohmic range has increased the capability of this lightweight solid state device to meet the urgent need for temperature-stable circuitry. A large positive temperature coefficient of 0.7% per °C and a constant predictable rate of resistance change with temperature make it ideal for temperature compensation and sensing from —50°C to +200°C in high frequency circuitry up to 20kmc.

Circle 116 on Reader Service Card

Germanium Tunnel Diodes

The RCA Semiconductor and Materials Division is currently offering germanium tunnel diodes to the electronics industry for experimental purposes on a commercial sampling basis. The tunnel diode can permit a greatly increased parts density, withstand cosmic and atomic radiation, and permit electronic computers to make up to a billion "decisions" a second. Also feature low noise, insensitivity to temperature changes, low power requirements, and freedom from surface effects.

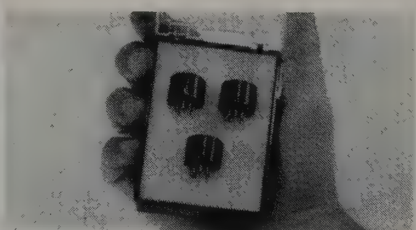
Circle 118 on Reader Service Card



Transistor Chopper Kit

Solid State Electronics Company announces the availability of a new circuit designer's plug-in transistorized chopper kit which contains Models 50P, 60P and 70P. These units are plug-in versions of the Models 50, 60 and 70 solder-in types. They are capable of linearly switching or chopping voltages over a wide dynamic range which extends down to a fraction of a millivolt and up to 10 volts. Models 50P and 60P are germanium units for operation from —55°c. to +99°c., whereas the Model 70P utilizes silicon transistors exclusively for high temperature applications up to 150°c.

Circle 160 on Reader Service Card



Silicon Transistor

Fairchild Semiconductor Corporation announces the 2N698, a high voltage diffused silicon transistor. The 120 volt collector to base rating allows wider voltage swings in amplifier and oscillator circuits plus more protection in inductive switching circuits. Maximum base saturation voltage is 1.3 volts. Has typical gain-bandwidth product of 90 mc. Typical neutralized power gain at 30 mc is 18 db and 2N698 will attain 30% oscillator efficiency at 70 mc. Power rating in TO-5 package is 2 watts at 25°C case temperature.

Circle 163 on Reader Service Card

UHF Mixer Diodes

The Semiconductor Division of Semi-Elements, Inc., has entered production on UHF Germanium Mixer Diodes which are precision designed and manufactured special for 1000 megacycle Mixer applications. Five different types are being produced, DC7, 7A thru 7D. d-c Current

average (Maximum) 25 ma, d-c Current Peak (Maximum) 75 ma, Temperature Range (Maximum) —50 to +75°C, Operating Frequency (Maximum) 1000 mc, Dissipation (Maximum) 250 mw.

Circle 136 on Reader Service Card

Switch Transistor Line

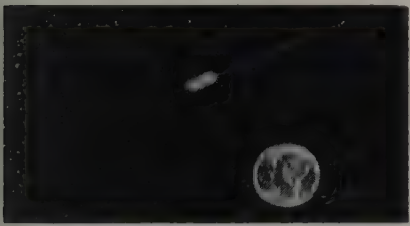
A new line of PNP silicon high speed switching transistors is available from the semiconductor division of Hughes Aircraft Company. The new series, designated as Types 2N1254 through 2N1259, provides a range of betas from 15 to 50, and a range of collector-to-emitter voltages from 15 to 50 volts. Operating temperature range is from —65°C to +160°C. They are also finding use as high frequency amplifiers in the 50 mc range, according to the company. Applications in this area include IF strips for missile telemetering systems. They also provide the designer with an opportunity to employ circuits involving NPN-PNP combinations.

Circle 139 on Reader Service Card

Subminiature Rectifiers

Solitron Devices, Inc., introduces a new line of hermetically encapsulated in metallized ceramic (L5 steatite and in high alumina to Mil-T-Spec) diffused silicon rectifiers. These subminiature rectifiers .300" long x .200" O.D., are available at 750mA- 200, 400, 600, 800 and 1000 volts, P.I.V.

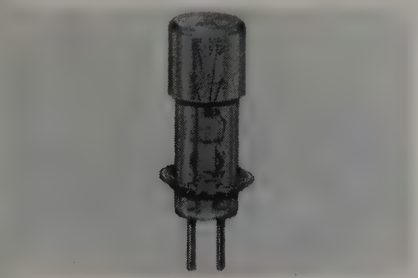
Circle 133 on Reader Service Card



Clip Mounted Lite

Transistor Electronics Corp. announces the release of their Clip Mounted Lite as the newest addition to their line of indicators. The CML-Series features single unit construction and press-on clip mounting. It mounts in a .294" hole and the circular clip permits mounting on ½" centers. Availible with a choice of neon or incandescent lamps, a choice of colors and with or without hot stamped legends. Connectors are by means of .040" plated terminals.

Circle 148 on Reader Service Card



Semiconductor Alloying Furnace

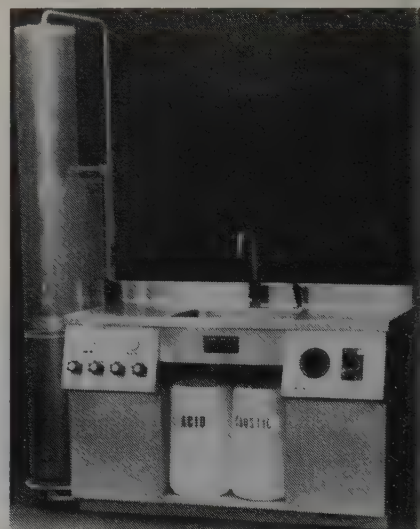
The Sandland Tool and Machine Company has started production of a new continuous firing, inert atmosphere alloying furnace. Model 20-D-2 was developed for producers of high quality semiconductor devices. It has provisions for precise control of temperatures up to 1875°F, precision control of speeds from 5/16 to 4″ per minute, and can maintain an inert atmosphere in the entire furnace.

Circle 120 on Reader Service Card

Resin Separator And Regenerator

The Penfield Mfg. Company Model SR-regenerating bench was developed primarily to supplement and provide means of using Model T-20 and PM-deionizers in order to produce the highest possible quality of deionized water such as used in manufacturing semiconductors. Consists of two cast polished acrylic plastic tubes, 10″ in diameter x 50″ high mounted on a stainless steel cabinet with complete stainless steel resin dump sump, drains, back splash plate and noncorrosive resin transfer pump and conductivity meter. All valves, piping and instrumentation necessary for the complete operation and final discharge to the canisters are incorporated in bench.

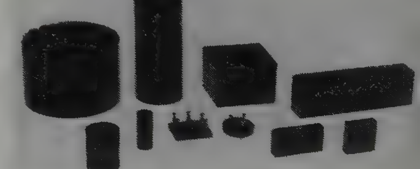
Circle 142 on Reader Service Card



Electronic Component Cases

High temperature epoxy electronic component cases are now available in a wide range of round, square and rectangular shapes and sizes from Plastronic Engineering Company. These cases serve as molds during potting of the electronic components, and simplify assembly line operations. In addition, they insure the required minimum amount of epoxy material around the encapsulated components and eliminate secondary patching operations frequently necessary with case packages.

Circle 144 on Reader Service Card



Silver Solder Rings

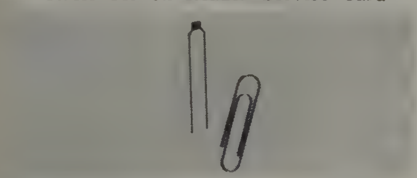
A new line of precision silver solder preform rings, designed for high speed soldering at temperatures ranging from 1150° to 1800°F, is now available from Alloys Unlimited, Inc. Depending upon the application, rings can be supplied with an overlap, a gap or with ends butted in diameters from .003 to .375" and with an almost unlimited range of inside diameters. The rings consist of an accurately predetermined amount of a specific silver solder alloy. This assures melting at the proper temperature and the correct volume of solder.

Circle 127 on Reader Service Card

Ceramic Capacitor

A high-temperature ceramic capacitor about twice the size of a pin head in values to 100 mmf has been developed by Vitramon, Incorporated, for use in encapsulated circuits. Called the "VK"-U series, these capacitors are designed for operation from —55° to 150°C at 200 vdc without derating. Other members of the same family offer values to 10,000 mmf in a progression of sizes to a maximum of 0.265" square by 0.070" thick. All units are guaranteed to minimum life of 1000 hours at maximum temperature and 200% of rated voltage after encapsulation.

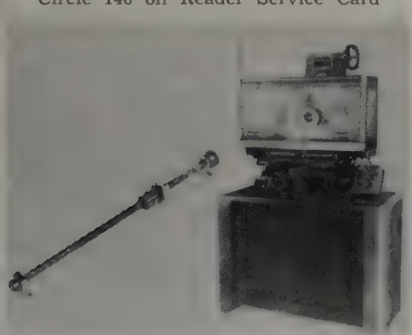
Circle 145 on Reader Service Card



Wafering Machine

Micromech Manufacturing Corp., announces the new Roton Table Drive Model of the Micro-Matic Precision Wafering Machine. Insures greater production efficiency in cutting germanium, silicon and other difficult-to-work materials. By providing a rolling rather than sliding fit between screw and nut, it gives a virtually frictionless drive thus allowing better slow speed control, higher rapid return speed as well as eliminating motor burnout.

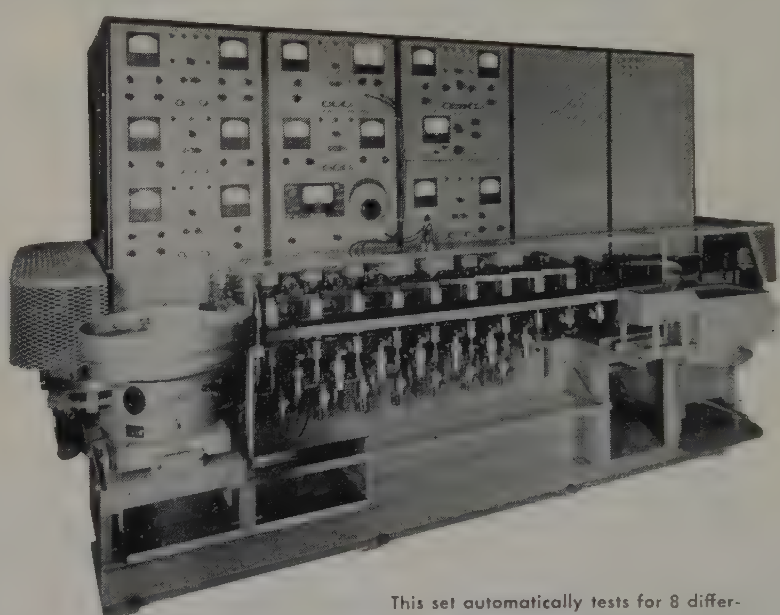
Circle 146 on Reader Service Card



Microwave Mixer Diodes

A new low in over-all noise figure in microwave mixer diode applications has been made possible by a matched pair of Ku band silicon microwave diodes, announced by Sylvania. Available in both forward and reverse polarities, when used as matched pairs, they virtually eliminate local oscillator noise, and will "provide a receiver system with a realistic 7.5 db over-all noise figure at the Ku band (16,000 mc region). Types 1N78D and 1N78DR effectively isolate the antenna and local oscillator terminals; also feature a maximum operating temperature of 150°C and complete hermetic seal.

Circle 121 on Reader Service Card



Silicon Crystal Growing Furnace

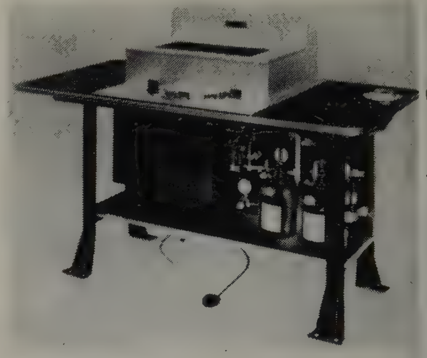
Hoffman Electronics Corporation has announced a new semiautomatic crystal growing furnace with triple production capacity. The furnace also is automated to reduce operational man hour requirements by 75 per cent. It produces monocrystalline silicon three times faster by growing ingots three times larger in the same period of time. Using the Czochralski method, it is capable of growing an ingot weighing up to 530 grams in 150 minutes or less.

Circle 117 on Reader Service Card

Parts Cleaner

Cobehn Precision Parts Cleaner (Model RT-S-8-6) critically cleans sensitive switches, relays, choppers, semiconductors and other precision components and assemblies at the rate of 600 units an hour. Parts are mounted around the periphery of a rotary turntable and automatically indexed to successive, high-velocity, spray-clean operations. A finely atomized spray of Cobehn solvent is combined with heated and filtered air and directed against all areas.

Circle 125 on Reader Service Card



Precious Metals

Gold, silver, platinum and other precious metals in the pure state or alloyed with N and P type materials are now available to the most stringent semiconductor specifications from Western Gold and Platinum Company. They are provided as fine diameter wire, ribbon, sheet, rings and preforms. Wesgo ceramics with up to 99.5% Al_2O_3 for good thermal conductivity and high mechanical strength are ideal for use in semi-conductor packages.

Circle 154 on Reader Service Card

Miniature Ceramic Capacitor

Cornell-Dubilier Electric Corp. announces the addition of a new, low-voltage, miniature ceramic disc capacitor to its "Tiny Mike" series. Designated as Type H, this capacitor is designed to meet the limited space, low-voltage requirements of transistorized radios, portable wire and tape recorders, electronic timing devices and a wide variety of other miniature battery-powered and line-powered equipment. Operating temperature range is +10°C to +85°C; working voltage is 50 volts DC.

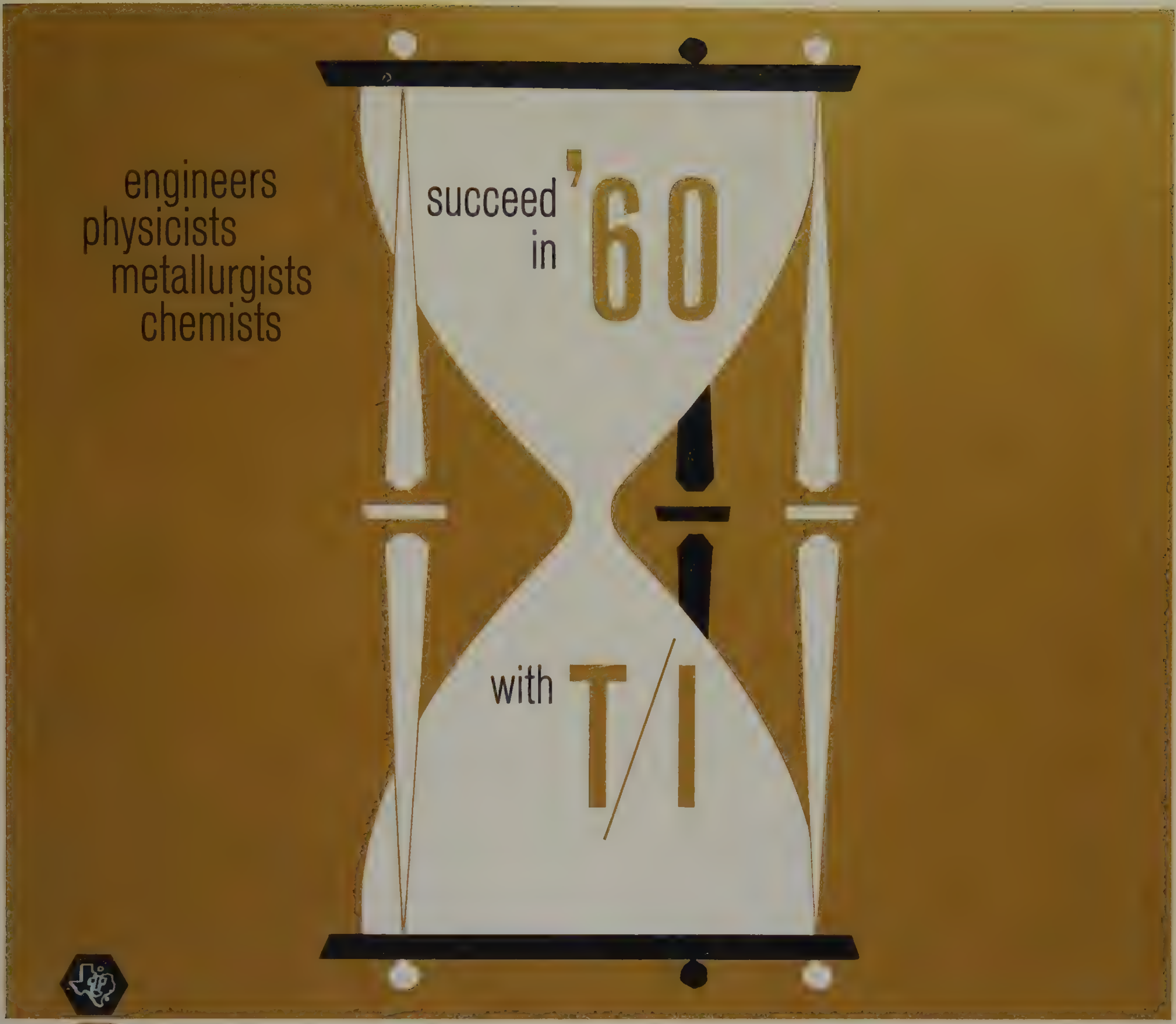
Circle 161 on Reader Service Card

Silicone Varnish

An all-new Class H silicone dipping and impregnating varnish that is as easy to process as most Class A and Class B varnishes has just been announced by Dow Corning Corporation. Designated Dow Corning 980 Varnish, this new material cures in only six hours at 150 C. Meets AIEE requirements for use in 220 C systems and has great heat stability. It resists moisture and is unaffected by many corrosive atmospheres.

Circle 143 on Reader Service Card

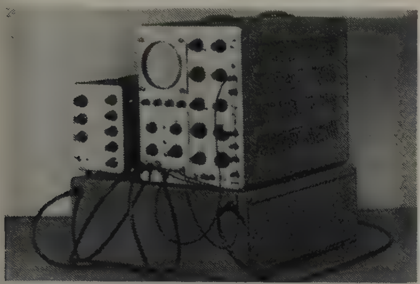
(Continued on page 91)


engineers
physicists
metallurgists
chemists
succeed in '60
with T/I

Pulse Sampling System

Recurrent signals faster than the normal capabilities of Tektronix Type 530, 540, and 550 Series Oscilloscopes can be observed with the Tektronix Pulse Sampling System. Risetimes to approximately 0.6 nsec (bandwidth to 600 mc) can be investigated. Displays with apparent sweep times of as little as one nsec can be provided (with magnifier, 100 picoseconds/cm). Provides general purpose medium and low speed service, convenient trigger takeoff, precise pulse generator with repetition rate of 720 pulses/sec nominally and risetime less than 0.25 nsec, ample signal delay, superior synchronizing, bright display, and high basic repetition rate to 100 kc.

Circle 130 on Reader Service Card



Vacuum Baking Oven

E. J. Stokes Corp. announces an improved version of their vacuum "baking oven" for outgassing and sealing semiconductor components under high vacuum. The manufacture of these components calls for the fabrication and assembly of thin slices of crystallized silicon, germanium, and other highly reactive materials. Outgassing these materials calls for a very high vacuum; certain other operations, such as fusing or sealing the component into the sub-assembly, require moderate amounts of heat and must therefore be carried out in a non-oxidizing environment. This oven is a self-contained "package" unit which produces this environment and provides an efficient method of carrying out these operations.

Circle 113 on Reader Service Card

Freon-Sonic Energy Cleaning System

Combining the advantages of Sonic Energy with the use of Freon as the solvent, a new system for highly critical cleaning applications was announced by Bendix Aviation Corporation, Pioneer-Central Division. For applications in which residual molecular film characteristic of chlorinated solvents, or where contact with water cannot be tolerated, the new system offers particular quality. Especially recommended for cleaning parts made from or containing beryllium, for ultra precise electronic components, or for other parts or assemblies, which are incompatible with hydrous solutions, but require absolute elimination of contaminants.

Circle 138 on Reader Service Card

Lead Telluride Photocell

A photoconductive cell for use in the infra-red regions is available from International Electronics Corp. Using cooled lead telluride, the 63 TV has a spectral response range of 0.6 to 6.0u with a peak response of 4.2u. The sensitivity of the cell is 1300 Volts rms per watt (peak to peak) and the signal to noise ratio is 500. These measurements are from a black body at 200°C. Increasing the temperature from 200°C to 500°C increases the sensitivity by 25.

Circle 131 on Reader Service Card

Military Type Diodes

Seven diodes designed to meet latest military specifications were announced by Silicon Transistor Corp. Three of the silicon glass diodes are general purpose types and four are fast switching. The general purpose types are: JAN types 1N457, 1N458, and 1N459. Of the fast switching types, there are: Signal Corps types 1N662, 1N663, 1N643 MIL and 1N658.

Circle 134 on Reader Service Card

Miniature Soldering Iron

A completely new type soldering iron has been developed by Caig Laboratories, known as the Ersa Minitype. The power supply for this low voltage (6 volts) iron may come from a battery or a special low voltage transformer. It has a 5 foot, light-weight, twin-cable, securely molded to the plastic handle and plug; weighs only 3 ounces. The slim shaped heating units of 10, 20 or 30 watts may be interchanged in the streamlined handle, in a matter of seconds to the desired wattage. A heat-up period of 40 seconds is sufficient. Has built-in protection against capacitative stray effects from mains which could damage transistors or endanger the operator.

Circle 123 on Reader Service Card

Hydrogen and Oxygen Leaks

The Jeps Co., formerly the Vacuum Products Division of Thomason Chemicals, announces the availability of a Hydrogen-Palladium Leak and of a new model of their Oxygen-Silver Leak. The obtainable leak rates are 0 to 100 micron-liters/second for hydrogen and 0 to 1 micron-liter/second for oxygen. The leaks may be sealed directly to hard glass systems. Graded seals are available for attachment to metal or other systems.

Circle 132 on Reader Service Card

New Diffusion Furnaces

A line of precision engineered gaseous and solid diffusion furnaces for the manufacture of quality transistors and semiconductor diodes has been announced by the Pilot Plant Equipment Division of Lindberg Engineering Company. Furnaces are available in single and multiple zone models, depending upon the temperature uniformity desired. Multiple tube models can be supplied, where floor space is at a premium.

Circle 152 on Reader Service Card

PNPN Diode Switch

A silicon *pnpn* diode capable of switching at extremely high speeds has been developed at Bell Telephone Laboratories. This device is useful in switching moderate amounts of power with extreme rapidity. Turn-on time is approximately ten millimicroseconds and turn-off time is about the same, including the storage time of the charge carriers, which is around 4 millimicroseconds. More refined measurements show that current is down four orders of magnitude in less than 100 millimicroseconds. Several watts of power can be switched by this device.

Circle 126 on Reader Service Card

Automatic Battery Chargers

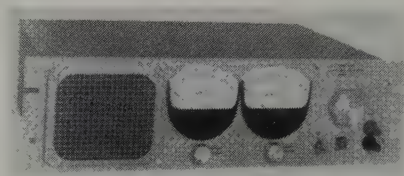
Christie Electric has announced a complete line of Automatic Battery Chargers for lead Acid, Nickel Cadmium, Silver Zinc Cadmium and Edison batteries. All units employ highest quality Silicon power rectifiers; and for stability and reliability Silicon diodes are also used in the control circuit. The standard line includes models ranging from 6 to 120 volts, 0-125 amperes output. Close end voltage regulation (±1%) is maintained for a change in a-c line voltage of (±10%).

Circle 119 on Reader Service Card

Transistorized Power Supplies

Quan-Tech Laboratories announces a new series of transistorized power supplies, #120, featuring highly regulated, low ripple output. Regulation of the solid-state, low-voltage power supplies is ±0.01% or ±3 mv from no load to full load or from 105V to 125V line. Ripple is less than 500 microvolts RMS. The four units, Models 121, 122, 123 and 124, have distinct but overlapping output voltage and current ranges—from 0.1 to 50 volts dc, and 0 to 5 amps.

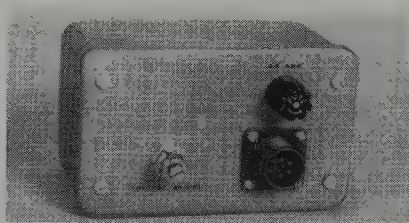
Circle 159 on Reader Service Card



Miniature Voltage Regulators

Highly regulated DC from unregulated DC sources is obtained by using the Valor Instruments transistorized Voltage Regulator. Output voltages ranging from 6 to 35 VDC are available from inputs ranging from 24 to 45 VDC. Specifications: Ripple Reduction 500:1 typical; Line Regulation ±0.1% or 10 mv whichever greater; Load Regulation 50 mv for 0-0.5 amp load change; Residual Noise 1 mv typical; Output Impedance 0.10 ohm maximum, DC-5KC; Size 3" x 3" x 5"; Weight 16 oz.

Circle 150 on Reader Service Card



Remote Masking Spray Coater

The development of a new machine, Model HD-2, for the accurate coating of coxial lead components by spray methods at a rate of 4000 per hour has been announced by Conforming Matrix Corporation. A resinous composition, such as an epoxy compound, can be used to completely form a light-tight seal for selenium diodes and other small electrical and electronic components, provided the coating material is sprayable.

Circle 137 on Reader Service Card

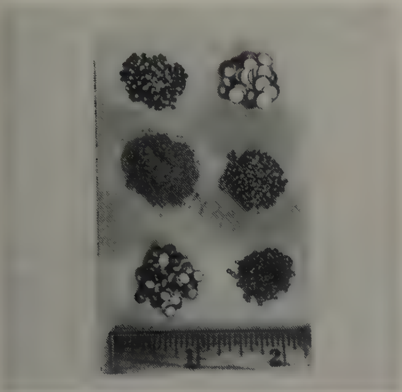
Transistorized Power Packs

Era Pacific, Inc., has added new units to its line of HYPAC miniaturized solid state high voltage DC power supplies. These are static semiconductor designs which include 1000-volt, 3000-volt and 5000-volt units with current ratings at 2 MA. Other specifications include input 105-125 VAC, 60 or 400 cps., line or load regulation better than ±0.5%, ripple less than 1% RMS.

Circle 158 on Reader Service Card

Semiconductor Preforms

Lead-antimony preforms for *n-p-n* type transistors are now available from Alpha Metals, Inc. The alloy combination most commonly used consists of 90% lead, 10% antimony, and has a melting point of 252° C. Other alloy combinations, too, are available. The purity of the metals used exceeds 99.999%. They are available as spheres, discs, cylinders, cubes, and are also preformed into drops, washers, rings and special shapes. Alpha fabricates this alloy as cylinders with a diameter of .008" and a thickness of .010" in production quantities.



Rectifier Power Supplies

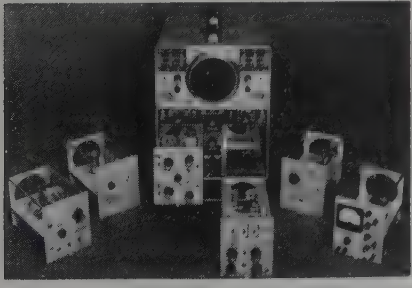
A complete line of semiconductor Rectifier Power Supplies for the production and testing of tantalum and other electrolytic capacitors, has been announced by Sel-Rex Rectifier Division, The Meaker Company, Subsidiary of Sel-Rex Corporation. The equipment is said to utilize newly developed, non-aging silicon or selenium elements, and vernier-controlled automatic programming for simple and precise adjustment of completely automatic formation process cycles.

Circle 149 on Reader Service Card

High Frequency Oscilloscope

A direct numerical reading oscilloscope has been introduced by Allen B. Du Mont Laboratories, Inc. The new high-frequency oscilloscope Model 425 is classed as an analog to digital converter. As a result of direct reading, accuracy is increased because the possible errors in interpolating and converting mathematically have been eliminated. Consists of 5 modules which may be interchanged. Can be operated by unskilled personnel and used for virtually every production line or industrial manufacturing process.

Circle 115 on Reader Service Card



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Personnel Notes

(from page 29)

Eastman Kodak Co. of Rochester, N. Y. where he was a senior design engineer. A graduate of the Carnegie Institute of Technology, Mr. Fisher formerly taught at the Rochester Institute of Technology and also spent three years with the U. S. Navy submarine service as an electronics specialist. He is a member of the American Institute of Electrical Engineers.

Dr. Murray Bloom has joined Pacific Semiconductors, Inc. to conduct research in organic chemistry, it was announced by Dr. Harper Q. North, president. Dr. Bloom was formerly associated with the American Potash and Chemical Co., and in his new affiliation will work with Dr. T. C. Hall in semiconductor surface research studies. The new PSI scientist received his Ph.D. degree from the University of California at Los Angeles in 1955.

Dr. Lloyd T. DeVore has been appointed director of engineering of the Laboratories Division, Hoffman Electronics Corporation, President H. Leslie Hoffman announced. Mr. Hoffman said the appointment was made to coordinate more effectively the division's research and engineering activity with advanced research at the Hoffman Science Center in Santa Barbara, Calif., which Dr. DeVore also heads. The new engineering director joined Hoffman a year ago, as a corporate vice president and director of the Science Center.

Anthony S. Gregorio has been appointed Product Engineer for diodes by Sperry Semiconductor, So. Norwalk, Connecticut. Mr. Gregorio comes to Sperry with thorough semiconductor experience, first at Sylvania Electric and then at CBS Electronics, where he was Engineer-in-Charge for Diodes. He studied Physics at M.I.T. and participated in specialized industrial study programs at Northwestern University. He is a member of the Institute of Radio Engineers, American Statistical Association and the American Society for Quality Control.

Thomas J. Murphy has been appointed Washington, D. C., Area Sales Engineer for Fairchild Semiconductor Corporation. He will maintain an office in the Fairchild Camera and Instrument suite, 1027 Cafritz Building, 1625 Eye Street, N. W., Washington, D. C. Fairchild Semiconductor recently became a wholly owned subsidiary of Fairchild Camera and Instrument Corporation.

The appointment of Jackson S. Kolp as product line manager, germanium switching transistors for the Semiconductor Division of Sylvania Electric Products Inc., has been announced by Elmer J. Perry, divisional manufacturing manager. In his new post, Mr. Kolp will be responsible for product engineering and production of NPN and PNP alloy switching transistors. He was formerly manager of commercial engineering for the division. Mr. Kolp joined Sylvania in 1946 as a design engineer at the company's development laboratory at Kew Gardens, N. Y.

Sam J. Karng has been named Department Head of Plant and Industrial Engineering at Sperry Semiconductor, So. Norwalk, Conn. This division of Sperry Rand Corporation is a leading manufacturer of high-quality silicon diodes and transistors. Mr. Karng brings to Sperry wide experience as a plant engineer. For eight years he was a plant engineer for General Electric Co. He received his BS in Mechanical Engineering at the University of Rochester and he is a graduate of GE's Manufacturing Training program.

Lindberg Engineering Company, manufacturers of industrial heat treating and process line equipment, has announced the appointment of Harold A. Moffat as salt bath furnace specialist. Mr. Moffat previously was responsible for sales and installation of scientific apparatus and heat treating furnaces in the Ohio and Pennsylvania areas. He will be headquartered at the expanded Los Angeles Plant and will service national and local accounts in the West Coast area.

Appointment of Clifford H. Lane as Manager, Industrial Semiconductor Products Department, RCA Semiconductor and Materials Division, was announced by Dr. A. M. Glover, Vice President and General Manager. Mr. Lane was previously Plant Manager of the Division's facility at Somerville. Dr. Glover pointed out that the new department, which Mr. Lane will direct, was established to meet current and future sales and operational requirements for the rapidly growing industrial semiconductor market.

Market News

(from page 83)

of an advanced anti-submarine warfare system. Delivery is scheduled to begin in 1961.

The firm also has been awarded two contracts by Convair Astronautics San Diego, California, to develop and produce 24 telemetry systems for the advanced space vehicle Centaur.

Military Contracts

General Instrument Corp., Semiconductor Div., 65 Gouverneur St., Newark 4, N.J. 1 Diode. Type 1N647, 24000, $52800, Contract N163-8132(X). 1 Diode, 1N647, 2200 each, $49500, Contract N163-8126.

Hoffman Semiconductor Div., Hoffman Electronics Corp., 920 Pitner Ave., Evanston, Ill. 1 Diode, Type 1N1530A, Contract N163-8130(X) 1500 each $32400.

Microwave Assoc., Inc., Burlington, Mass. $27,500.00 for semiconductor devices, type 1N23C. IFB-362.

Rheem Semiconductor Corp., Mountain View, Cal., $5,432 for 1 item of semiconductor devices, type 348C19287-1. IFB-457.

General Instrument Corp., Newark, N.J., $6,000 for 1 item of semiconductor devices, type 212-G11A. IFB-460.

Sperry Semiconductor Div. Sperry Rand Corp., So. Norwalk, Conn., $11,875.50 for 1 item of transistors type 2N328. IFB-531.

Sterling Electronics Inc. Houston Tex. Est. $26,472.58 for 4 varying items of semiconductor devices, type 1N69A. IFB-497.

Sylvania Electric Prods., N. Y., N. Y., $9,380.00 for 1 item of diodes, type 1N25. IFB-503.

Western Electric Co., N. Y., N. Y., $5,380.00 for 1 item of transistors, type 2N463. IFB-525.

A split award to International Rectifier Corp., El Segundo, Cal., $9,252.88 for 1 item of semiconductor devices, type 1N538; Sylvania Electric Prods., N. Y., N. Y., $1,792.65 for 1 item. IFB-540.

A split award to Sylvania Electric, Woburn, Mass., $389.08 for 1 item of transistors, type 2N498; Texas Instruments, Dallas, Tex., $10,000.00 for 1 item. IFB-530.

A split award to U. S. Semiconductor Prods., Phoenix, Ariz., $875 for 1 item of semiconductor devices, type 1N429; Transitron Electronic Corp., Wakefield, Mass., $5,625 for 1 item; Bomac Labs., Inc., Beverly, Mass., $2,490 for 1 item. IFB-404.

NEW SERVICE NOW AVAILABLE

SEMICONDUCTOR PRODUCTS is making a new source of information available to all firms interested in being kept up to date on materials or equipment for producing semiconductor devices. If you wish to receive all new literature on silicon, germanium, chemicals, machinery, or other such materials, circle #99 on the reader-service card. Your name will be placed on a special list which will be forwarded to all such suppliers. As these suppliers have news available in their field, you'll be notified by them immediately. This service is restricted to firms manufacturing semiconductor devices or firms contemplating entering into production within 120 days.

Industry News . . .

CONFERENCE CALENDAR

The Following April 1960 Meetings Are Scheduled:

April 3-8 — 6th Nuclear Congress, New York Coliseum & Waldorf Astoria Hotel, New York City. Sponsored by Engineers Joint Council, ISA, ASME, PGNS-IRE. For Information: USAEC N. Y. Operations Office, M. E. Cassidy, 376 Hudson Street, New York 14, N. Y.

April 4-6 — AIEE Southwest District Meeting, Houston, Texas.

April 5-9 — Electrical Engineers Exhibition, Earls Court, London, England

April 7-8 — Management Engineering Conference, Statler-Hilton Hotel, New York City. Sponsored by SAM, ASME.

April 7-9 — Optical Society of America, Spring Meeting, Hotel Statler, Washington, D. C. Sponsored by AIP.

April 5-14 — American Chemical Society, 137th National Meeting, Cleveland, Ohio.

April 12-13 — 14th Annual Spring Technical Conference on Electronic Data Processing, Hotel Alms, Cincinnati, Ohio. Sponsored by Cincinnati Section ARS. For Information: S. W. Stuhlbarg, Avco Corp., Crosley Div., 1329 Arlington Street, Cincinnati, Ohio.

April 18-19 — Conference on Automatic Techniques, Sheraton Cleveland Hotel, Cleveland, Ohio. Sponsored by PGIE, AIEE, ASME. For Information: L. W. Herschenroeder, Industry Eng., Westinghouse, East Pittsburgh, Pa.

April 19-21 — International Symposium on Active Networks & Feedback Systems, Engineering Societies Building Auditorium, New York City. Sponsored by PGCT, PIB, ONR, OSR, USASROL. For Information: Herbert J. Carlin-Polytechnic Institute of Brooklyn, 55 Johnson Street, Brooklyn, N. Y.

April 20-22 — SWIRECO, S. W. IRE Regional Conference & Electronic Show & National PG on Medical Electronics Conference. Shamrock-Hilton Hotel, Houston, Texas. Sponsored by Region 6, PGME. For Information: Ralph T. Dosher, Jr., Texas Instruments, Inc. P. O. Box 6027, Houston 6, Texas.

April 25-28 — American Physical Society Meeting, Willard Hotel, Washington, D. C. Sponsored by AIP.

April 25-29 — 41st Annual Convention & Welding Exposition, Great Western Exhibit Center and Biltmore Hotel, Los Angeles, Calif. Sponsored by the American Welding Society. For Information: American Welding Society, 33 W. 39th Street, New York 18, N. Y.

April 27-29 — AIEE Great Lakes District Meeting, Milwaukee, Wisc.

April 29-May 1 — Producers of Associated Components for Electronics, Annual Meeting, Nevele Hotel & Country Club, Ellenville, N. Y.

RESEARCH & DEVELOPMENT

A special Glycerine Application Research Award was presented by the Glycerine Producers' Association to Anthony J. Certa, Project Engineer, Chemical Projects Group; Thomas J. Manns, Engineering Section Manager; and George L. Schnable, Engineering Group Supervisor, Chemical Projects Group, all of Lansdale Tube Company, Division of Philco Corporation, Lansdale, Pennsylvania. The special award was made to the research team for the development of glycerine baths for electrodeposition of various low-melting metals and alloys, a major technological advance that permits automated, mass-production soldering of extremely delicate lead wires to high frequency transistors used in very high speed, solid state computers and high frequency transistorized communications equipment. The new technique for soldering small wires to transistors is reported to be the first, and thus far, only method for satisfactory high speed production. Previously, the only acceptable method consisted of direct soldering of the "whisker" wires to the extremely small electrodes involved (frequency 0.001 inch to 0.005 inch diameter). In the new method, microgram quantities of molten solder are electroplated on the whisker wire, which is then brought into contact with the transistor electrode in the presence of a sufficient heat to cause the solder to flow and produce a satisfactory bond. The research team reports that the new approach has played a major role in making possible the production of high frequency transistors.

(For Further Details Circle No. 200 on Reader Service Card)

Vast unprobed secrets of nuclear forces are now being uncovered by means of a "solid state ionization chamber" smaller than the head of a pin, a scientist of Hughes Aircraft Company revealed recently. The new device has important applications in space exploration, military uses, nuclear power control, cancer treatment, industrial processes, basic nuclear research and other fields, according to Dr. Stephen S. Friedland. It is actually an innovational radiation detector developed and produced by a team of nuclear physicists and solid state physicists in Hughes' laboratories at Los Angeles and Newport Beach, Cal. The work was carried out under the company's general research program but additional support was received from Defense Atomic Support Agency, the government agency which is responsible for planning and conducting of field tests of nuclear weapons.

"The value of the Hughes detector lies in its ability to make measurements that up to now simply could not be made," Dr. Friedland said. "It measures the number and energy of atomic particles traveling at speeds faster than man can comprehend. It performs with far greater effectiveness than earlier detectors, is far less cumbersome and costs less. The detector is essentially a slice of 'doped' silicon so thin as to be barely discernible to the eye. When struck by a charged nuclear particle it emits a pulse which can be measured and analyzed, providing us with information we need to know and often could not obtain before."

(Continued on page 98)

Industry News—R & D

(from page 96)

General Electric research scientists have successfully made tunnel diodes work at frequencies above 4000-megacycles (four billion cycles), the company revealed. In addition, most other performance characteristics exceed those of previous tunnel diodes, G. E. stated.

Key to the improved performance is the use of gallium arsenide, a little known and rarely used semiconductor material, as the basic element in the device's construction. G. E. credited Dr. R. N. Hall of its Research Laboratory in Schenectady and Drs. N. Holonyak, Jr. and I. A. Lesk of its Advanced Semiconductor Laboratory in Syracuse for the gallium arsenide tunnel diode developments. G. E. scientists stated that based on their present observations gallium arsenide is the best material for tunnel diodes so far explored and may be the ultimate material for the best overall performance. Oscillation frequencies of 4400-megacycles have been obtained indicating that frequencies well above 10,000-megacycles are possible with tunnel diodes made of gallium arsenide.

A method of making silicon p-n layers directly from the vapor phase growth of single crystal production has been invented by scientists of the Merck research laboratories' Advanced Electronic Materials Section. In this new procedure, alternate p and n single crystal layers are deposited from the vapor phase. The process permits close control of resistivity, thickness, and other parameters of junctions. The technique is a new approach to the formation of semiconductor junctions, now made by alloying or diffusing processes. Complex junction configurations can be made by using the deposition process. John Allegretti and Dr. Donald Shombert, Merck scientists participating in the new development, feel the new technique may find use in the field of solid circuits or "molecular electronics," where slabs of single crystal silicon containing many parallel junctions could serve as the base for micromodules. Ultimate potential of this new approach will depend on evaluations by device manufacturers, according to Dr. George Krsek, Director of the company's Electronic Chemicals Division. They are now preparing to distribute samples of the junctions to the device industry, he added.

Scientists at Bell Telephone Laboratories are creating their own problems in characterizing Esaki (or "tunnel") diodes as they push the operating speeds of these devices up and up. However, according to Donald E. Thomas, new techniques have been developed for stabilizing and evaluating the characteristics of the tiny new devices which have proven very successful for germanium and silicon diodes with time constants in the order of 10^{-10} seconds.

These methods have also worked for indium antimonide diodes having speeds several times faster. However, new models being devised by Robert L. Batdorf and other members of the Laboratories are so fast that they are beyond present stabilization techniques. One such diode has switched a quarter volt in less than the time it takes light to travel 2-½ inches.

Mr. Thomas described an improved technique to a meeting of the American Institute of Electrical Engineers in New York, giving a direct plot of the VI curve of the diode with its negative resistance region. The stabilization methods used for negative resistance curve tracing are also useful in measuring the junction capacitance of the diode. Techniques for measuring the diode capacitance were also described by Mr. Thomas.

The characterization methods described have been extremely helpful in research and development efforts aimed at improved diodes for still faster operation.

(Continued on page 100)

Industry News—R & D

(from page 98)

A new whisker-sized semiconductor strain sensing element that can provide aircraft or missiles with strain gauges possessing sensitivities 50 times greater than present metallic devices has been developed by Electro-Optical Systems, Inc., and the Army Ordnance Corps' Picatinny Arsenal in Dover, New Jersey. This microminiaturized sensing mechanism is also applicable to transducer applications in the measurement of pressure, linear and angular acceleration, vibration, displacement, and force. Its extreme sensitivity also makes it usable in hydrophones and similar listening devices, EOS scientists state. Measurement characteristics of the whisker sensing element stem from the piezoresistive effect.

In replacing conventional strain measuring components, the whisker boasts an ultimate gauge factor of 175 compared to less than five for wire strain elements now in use. Single crystal construction of the element endows it with extremely high strength enabling it to accommodate overloads that would cause permanent deformation in its metallic counterparts. This composition also eliminates element hysteresis and provides it with improved linearity. The whisker can be bent into a complete loop without breakage and still return precisely to its original position.

A miniature automatic assembly line is now turning out computer transistors at the rate of 1,800 an hour. International Business Machines Corp. said that its engineers have developed a new automated transistor assembly system for making the tiny devices that have become essential to the manufacture of most advanced data processing equipment. Designed and engineered at IBM's Poughkeepsie plant, the machine has successfully completed its first test-month of production. The new IBM machine is roughly five times faster than the semi-automated assembly of transistors now in general use. It has the highest production rate of the few existing automatic methods. Holding to tolerances as close as 0.0005 inch, the machine is able to produce transistors of greater uniformity than those made by previous methods. IBM's system is the first automated means of making the *n-p-n* alloy junction transistor. With modification, the system can produce any type of alloyed transistor.

A major step forward in telephone technique was taken recently in Paris, France with the introduction of a 240-line fully electronic private telephone exchange whose control circuit operates 10,000 times faster than the electromechanical exchanges now used throughout the world. The telephone exchange was put into regular operation and demonstated by International Telephone and Telegraph Corporation at the Laboratoire Central de Telecommunications, ITT's French associate research company which developed the equipment. The registering itself is effected by magnetic memories made of minute ferrite cores. The logic operation, started by the storing of the called number, is devoted to single 'logic circuit' which replaces all the registers. It is fundamentally made of diodes and transistors and its activity is shared by the 240 subscribers. It is periodically assigned to each of the calling lines and each time it advances one step further towards the solution to the problem raised by each call. Following the decisions of the logic circuit the communications are established through electronic contacts made of cold-cathode gas tubes that are switched on or off in one thousandth of a second. After all information has been inserted into the electronic exchange, the speed of operation is equivalent to connecting 60 calls per second.

New Literature

The very latest prices, listings and data are carried in a new issue of Ohmite Manufacturing Company's 32-page, 2-color Stock Catalog No. 30A. This is the biggest catalog to date of those items stocked by Ohmite and its distributors for immediate delivery. A complete line of power rheostats listed here includes the new Model E miniature size. Also shown are extra-heavy current "Powr-Rib" and "Corrib" resistors; new molded composition resistor sizes. Stock listings of tantalum capacitors in all three types, wire, slug, and foil, have been increased considerably.

Circle 165 on Reader Service Card

A new bulletin with technical data for seven silicon glass diodes manufactured to conform to military specifications is now available from Silicon Transistor Corp. The new sheet, consisting of two pages, includes specifications, curves, and illustrations of the following military type silicon glass diodes: 1N457, 1N458, 1N459, 1N643, 1N658, 1N662 and 1N663.

Circle 166 on Reader Service Card

Bulletin No. 151, "Lindberg-Upton Salt Bath Furnaces" is now available from Lindberg Engineering Company. This brochure describes and illustrates the advantages of the graphite "continuing" electrodes in salt bath furnaces. The brochure also describes and illustrates high and low temperature salt bath furnaces for any production, pilot plant or laboratory use.

Circle 167 on Reader Service Card

Designed for transistor circuit applications, a series of transistorized power supplies are fully described in bulletin PS1059 from Valor Instruments. The series delivers variable and fixed outputs, ranging from 1.5 to 50 volts DC and 2 to 5 amps with high line and load regulation. Complete information on transient response, ripple, stability, regulation, output impedance, controls, weight, packaging and price is provided.

Circle 168 on Reader Service Card

A new brochure on miniature, epoxy molded transformers for use with transistors in printed circuits has been released by Triad Transformer Corporation, a division of Litton Industries. This brochure describes in detail the applications and uses of Triad's SP or "Red Spec" series transformers. It gives engineering data, electrical specifications and mechanical dimensions.

Circle 169 on Reader Service Card

A new VECO Data Book has been published by Victory Engineering Corp., covering thermistors and varistors, thermal conductivity cells, electronic controls and thermal, electronic and physical-sensing devices. The new Data Book includes R vs T curves and E vs I curves,

(Continued next page)

plus additional information on VECO Silicon Carbide Varistors including curves. Available at a nominal cost.

Circle 170 on Reader Service Card

Second issue of Donner Tech Notes, a 4-page publication describing analog computer techniques and applications, is available from Donner Scientific Company. Feature article in this issue is entitled, "How to Use and Program Analog Computers". Two problems are investigated to show the techniques involved: the suspended pendulum and the inverted pendulum. The first problem lends itself easily to analytical solution, the second is far more complex.

Circle 171 on Reader Service Card

Sigmund Cohn, metallurgists and specialists in wire products, has announced the publication of an 8-page brochure entitled "Precious Metals and High Purity Nickel as used in Temperature Measurement." It discusses the advantages of using Platinum and Platinum Alloys as both resistance thermometer elements and as thermocouples in the measurement of high temperatures. Some of the pages cover Platinum vs Platinum Rhodium thermocouple wire, Iridium vs Iridium-Rhodium, Gold-Cobalt vs Silver-Gold. Included is a section devoted to the use of Platinum and High Purity Nickel for Resistance Thermometer Elements.

Circle 172 on Reader Service Card

Wallson Associates, Inc. announces the availability of their new data sheet 106. This technical data sheet contains a detailed description of the completely self-contained Wallson 20 Ampere Dynamic Rectifier Analyzer known as Model 141A. Forward current and reverse voltage are independently adjustable. Full scale meter ranges are provided.

Circle 173 on Reader Service Card

Bulletin No. 287A, four pages, describes the new Radio Receptor Tri-Amp rectifier. A completely new concept in selenium, it is manufactured without an artificial barrier layer, thus eliminating the cause of aging and high voltage drop. Rectification is accomplished through a P-N junction formed by a closely controlled diffusion process. The bulletin is descriptive of the stack coding system, a computation table for stack dimensions, and cell rating tables for both convection and forced air cooling. Typical performance characteristic curves are also shown.

Circle 174 on Reader Service Card

"Current Uses for Electroforming—a Manual for Designers, Engineers and Manufacturers" is a technical handbook just published by Allied Research & Engineering Div., electroforming specialists. Profusely illustrated, the 32-page book incorporates the latest technical information on electroforming. Included are chapters on what the electroforming process is, where it is used, "do's and don'ts" for designers, and charts and tables of engineering data.

Circle 175 on Reader Service Card

A new data sheet describing Essex Electronics' latest addition to their broad

(Continued next page)

line of RF chokes and pulse transformers has been published. The data sheet contains a detailed description of the electrical parameters for the complete line of Variable Inductors, which are available in a range of inductances from 0.10 μH to 4700 μH in 29 overlapping ranges.

Circle 176 on Reader Service Card

A nineteen page brochure from Designers for Industry, Inc., illustrates electronic projects completed for the defense department and commercial clients. Radar systems featuring size and weight reduction, transistorized X-band radar and transponder beacons are described. Military communications projects are illustrated by photographs and line drawings. An Airborne Manual and Panoramic Receiver, Missile Electronic Program Generator, Air to Ground Transceiver and a Mobile Communications Center are some of the subjects illustrated.

Circle 177 on Reader Service Card

A new four-page catalog describing Aerovox Type QE high quality, long life, computer grade electrolytic capacitors is available from Aerovox Corporation. Literature provides complete technical information on these high reliability units including dimensional drawings, performance characteristics and table of stock values.

Circle 178 on Reader Service Card

Bulletin No. 308, four pages, is a listing of selected power stack assemblies, ranging from 3 to 30 kw *d-c* output, using the new Radio Receptor selenium Tri-Amp rectifiers. Design data is shown for units of 125 and 250 volts *d-c*, convection and forced air cooling. The required *a-c* input voltage and the rated output in kw and amperes is shown for each unit. List prices are given for each stack and group assembly.

Circle 179 on Reader Service Card

A brochure describing a method of application of coating compounds to small articles, such as electrical and electronic components at a rate of 4,000 per hour, is being offered by Conforming Matrix Corporaton. It tells how sprayable resinous compositions, such as epoxy compounds, can be used to completely form a light tight seal for selenium diodes.

Circle 180 on Reader Service Card

Tele-Dynamics Inc. offers a 12-page, two-color illustrated brochure, Number 935, which describes the new ruggedized commutator, transistorized pulse-width modulator, and crystal-stabilized transmitter designed especially for airborne PDM telemetry systems. The brochure includes detailed electrical, environmental, and physical characteristics in addition to outline drawings.

Circle 181 on Reader Service Card

Schweber Electronics is offering a buyers and engineers guide to aid in the selection of miniature K and D subminiature Cannon Connectors, in the form of a two-color four page folder. The brochure gives detailed information including appropriate hardware and accessories.

Circle 182 on Reader Service Card

(Continued next page)

A sixteen page, high-reliability capacitor catalog has just been published by the Electron Products division of Marshall Industries. Complete electrical specifications, temperature characteristic graphs and construction details are presented for engineering reference. A wide variety of capacitor types and case styles are featured.

Circle 183 on Reader Service Card

A new 16 page catalog contains complete specification data for every DC Power Supply in Dressen-Barnes' standard line (75 Power Supplies). A Power Supply Selection Chart has been combined into the catalog that permits the user to select his output requirements and turn, in seconds, to the complete data for D/B Supplies that fulfill his requirements. This catalog represents twelve years of data compilation.

Circle 184 on Reader Service Card

Electronic Research Associates, Inc., announces the availability of a two-color catalog sheet which describes the company's new line of Transpac high voltage, miniaturized, solid state power packs. The catalog sheet provides descriptive material on these units, lists available model types, includes specification data, and current pricing information.

Circle 185 on Reader Service Card

Available from Bendix Aviation Corp., Semiconductor Products Division, is a data sheet on their new military-type germanium pnp power transistor, 2N1011. Sheet gives absolute maximum ratings, thermal resistance, electrical test data, mechanical dimensions, etc., of this transistor.

Circle 186 on Reader Service Card

Available now is the 1959 International Edition of the Electronic Guide. This first issue of the Directory lists more than 4700 articles which have appeared in numerous technical publications. Simplicity of preparation of this information should be most helpful to researchers. The Editor, David Early, is actively engaged as a consulting research engineer and design specialist. Cost of publication will be furnished with replies to inquiries.

Circle 187 on Reader Service Card

Kahle Engineering Company has issued eleven pages to be added to their catalog. The last catalog mailing was February 1958. A sheet for each of the following is available. Automatic Final-Seal Machine for all types of glass diodes; Automatic Cat Whisker Machine for all types of diodes; Automatic Cat Whisker Machine for special purpose; Crystal Mounting Machine (semi-automatic) for Diodes and Transistors; Crystal Refining and Purifying Machine; Zone Refiner, Horizontal Type; Glass-case (Body) Cleaning Machine for diodes, etc.; Button Stem Machine for sub-miniature tubes, used also for transistors; Automatic Glass Hole Punching Machine; Automatic Sealing-Exhaust Machine; Neck Sealing Machine with Molded Seal; Automatic Striping and Painting Machine.

Circle 188 on Reader Service Card

INDEX TO ADVERTISERS

6

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KNAPIC specializes in Silicon and Germanium Crystals for Semiconductor, Solar Cell and Infrared uses

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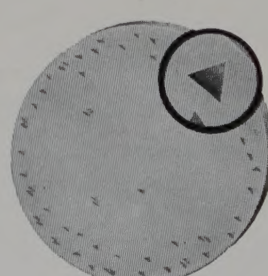

Dislocation density, Knapic silicon monocrystals grown by a modified Czochralski technique: Crystal diameter to ⅜"—None; ⅜" to ¾"—less than 10 per sq. cm.; ¾" to 1¼"—less than 100 per sq. cm.; 1½" to 2" less than 1000 per sq. cm.

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